TRAFFIC INJURY RESEARCH FOUNDATION


# EVALUATION OF THE PHOTO ENFORCEMENT SAFETY PROGRAM OF THE CITY OF WINNIPEG

## FINAL REPORT

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# EVALUATION OF THE PHOTO ENFORCEMENT SAFETY PROGRAM OF THE CITY OF WINNIPEG: FINAL REPORT

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# EXECUTIVE SUMMARY

- The Traffic Injury Research Foundation (TIRF) was contracted by the City of Winnipeg to evaluate the Winnipeg photo enforcement safety program of the Traffic Safety Unit of the Winnipeg Police Service. The evaluation project began in the Spring of 2008.

- The components of the evaluation include:
  - a review of the literature about photo enforcement;
  - a process evaluation of Winnipeg's photo enforcement safety program;
  - a public opinion poll in Winnipeg about the photo enforcement safety program;
  - an analysis of the effect of photo enforcement on traffic safety in the municipality using crash data;
  - a controlled study evaluating the impact of photo enforcement at intersections on speed and red light violations; and,
  - a controlled study evaluating the impact of mobile photo radar on speed at schools and construction sites.

- Information about the implementation of the program and how it has been/is being delivered was collected in 2010 through in-depth interviews with key people involved in the project for the purposes of the process evaluation. A wide variety of relevant documents pertaining to the program were also reviewed to provide additional detail about key program components, strategies and challenges.
- A public opinion poll was conducted among residents within the Winnipeg Central Metropolitan Area (CMA) in May 2009. The public opinion poll examined both the knowledge and opinions of drivers with respect to Winnipeg's photo enforcement program using appropriate statistical methods.
- Time series analyses were performed to investigate trends regarding collisions, injuries and crash severity before and after the implementation of photo enforcement in Winnipeg. Winnipeg collision data were used to develop a database containing time series of monthly collision counts from 1994 through 2008 in Winnipeg and are used along with control group data from New Brunswick.
- An intersection camera experiment was conducted using roadside data on speeding and red-light running behaviour to examine the effect of the intersection safety cameras.
- Finally, an experiment was conducted using data regarding the effectiveness of mobile photo radar on speeding behaviour.

## Results

- There is a large body of literature demonstrating the positive impact of photo enforcement programs. Results of a minority of studies do raise some questions about the effectiveness of this strategy. Nevertheless, a consensus exists among a majority of researchers in the field that photo enforcement is an effective safety measure. Some researchers voice concerns about undesirable side effects such as possible increases in rear end crashes and encourage more research to further investigate optimal conditions for these programs.
- The process evaluation showed that program operations are well-managed and issues that do emerge are easily resolved and dealt with accordingly. There are some issues that will require ongoing attention.
- The public opinion poll results show that a clear majority of respondents are concerned about running red lights, but fewer people seem to be concerned with speeding. Approximately 95% seem to be aware of Winnipeg's photo enforcement safety program; 71% believe the program helps improve road safety in Winnipeg; approximately 80% think the photo enforcement safety program makes the public more aware of the issue of speeding; and, 81% support the continuation of the photo enforcement safety program.
- Regarding the results from the time series analyses of red light running crashes, when considering the strongest evidence only (effects significant at 5% level), there was a 46% decrease in right angle crashes at camera intersections and a 42% increase in rear end crashes. Given that rear end crashes are typically less severe than right angle crashes and the fact that this negative side effect can be rectified using mitigating strategies such as improving signage and education about the functioning of the photo cameras, it appears the photo enforcement safety program has had a positive net effect on traffic safety in the city of Winnipeg.
- The 42% increase in rear end crashes was followed by a decrease but this decrease was less significant. When considering all the evidence including these less significant effects (i.e., effects that are only significant at the 10% level), it can be concluded that there was a 46% decrease in right angle crashes at camera intersections and only a 15% increase in rear end crashes. However, the evidence then also suggests there was a 25% increase in rear end crashes at other intersections in Winnipeg without cameras. Again, this would suggest mitigating strategies are required to combat these negative side effects, not only in the vicinity of camera intersections, but throughout the entire city of Winnipeg. Further monitoring will be required.
- Regarding the results from the time series analyses of speeding related crashes, when only considering the strongest evidence (significant at 5% level), there were no increases or decreases in injury crashes or pdo crashes, not at the camera intersections and not at other intersections in Winnipeg. When considering all the evidence (i.e., including effects significant at the 10% level), it can be concluded that there was a 24% decrease in injury crashes at camera intersections, a 13% decrease in pdo crashes at camera intersections and a 2% increase in pdo crashes at other intersections without cameras.

> Of importance, while it was possible to analyze and describe the impact of the photo enforcement program on safety levels in Winnipeg, it is more challenging to better understand how these effects were established. This is due to the fact that this evaluation was designed to assess the impact of the photo enforcement safety program as a whole, i.e., how did it impact on Winnipeg safety levels in its entirety, rather than studying specific sites or intersections. This, in combination with the lack of information or documentation regarding the criteria used in selecting locations for cameras makes it difficult to attribute the results from the time series to important aspects of the photo enforcement program, such as the number of camera locations, the timelines of installing more cameras over time, the specific locations of those cameras, or the combination of increased or enhanced educational efforts with the installation of cameras.

> The intersection camera experiment shows that there were either decreases in speeding violations at the experimental site compared to smaller decreases or increases at the control sites; or, there were increases in speeding violations at the experimental site that were smaller than the increases at the control sites. In other words, the photo enforcement program has a clear protective effect that increases levels of traffic safety. However, the data also suggest that photo enforcement may be less effective in preventing serious speeding violations. This may be due to the fact that research shows serious speeding violations are more commonly committed by high-risk drivers for whom many traffic safety measures are less effective.

> Further, based on the results from the intersection camera experiment, patterns of serious speeding violations differed across experimental sites suggesting that there are differences in the intersection design between those experimental locations. Such differences need further investigation in an effort to enhance understanding of how best to implement photo enforcement.

> Regarding red light running violations, the intersection camera experiment clearly shows a positive impact of photo enforcement with significantly fewer violations after the installation of cameras.

> Data were collected to also evaluate the photo radar aspect of the program. Unfortunately, due to limitations of the data it was not possible to draw any meaningful conclusions about the effectiveness of these mobile radar cameras.

## Recommendations from the Process Evaluation

> Improve the documentation of key program decisions and their associated decision-making criteria.

> Seek external expert input regarding financial projections associated with the program.

> Enhance program partnerships to improve existing data sources or to make available new data sources that can augment program measures and provide additional information regarding the photo enforcement program. It is recommended that the Winnipeg Police Service continue to work with Manitoba Public Insurance to improve available data sources for both the management and evaluation of the program.

- Augment existing performance measures with additional program measures to increase understanding of the program and provide new windows on its operation.
- Explore the feasibility of and level of support for strategies to transition to digital technology so that informed decisions can be reached and, if needed, a reasonable plan and timelines can be developed to effectively manage this transition.
- Consider a periodic review of the decision to limit photo radar to only specific locations. Results from this large-scale evaluation can be used to inform knowledge about program effectiveness, provide a range of insights into the different aspects of program operations, and provide a sound basis for decision-making.

## Recommendations from the Public Opinion Poll

- Ensure levels of concern about road safety and speeding are appropriate. This would presumably lead to more people abiding by the rules with less speeding and red-light running infractions as a result.
- Continue to educate those who are less supportive of the photo enforcement safety program about how it improves road safety. People may underestimate the true magnitude of the problem of speeding and red light running or the effectiveness of photo enforcement. With more education people may better understand the true extent of the problem and be less likely to underestimate it. This can lead to more appropriate levels of concern about speeding and red light running and higher levels of support for the program.
- It may also be useful to ensure that people who are detected and received a ticket understand their behaviour is dangerous. This speaks to the importance of education.

## Recommendations from the Time Series Analyses

- While the overall results from this portion of the evaluation clearly support the continuation of the photo enforcement program, the evidence also shows there has been an increase in rear end crashes at camera intersections and likely at other intersections without cameras in Winnipeg too. For this reason, a strategy should be designed that can help mitigate this increase in rear end crashes. Such a strategy can include improved signage regarding the use of photo enforcement to ensure drivers get sufficient notice when approaching an intersections as well as education for drivers about this negative side effect.
- It is also recommended to update the analyses when more crash data become available to further monitor crash levels in Winnipeg.
- Finally, further research is needed to shed light on mechanisms that can help explain why the photo enforcement safety program is effective and how it can best be improved.

## Recommendations from the Intersection Camera Experiment

> Further research into the profile and behaviour of offenders who commit serious violations is recommended and will be useful in determining how such offenders should be managed and how the photo enforcement program can be further improved.

> Conduct further research into infrastructure and engineering differences between intersections that might explain differences in performance of photo enforcement at intersections including further examination of the literature along with a detailed and controlled experiment.

## Recommendations from the Photo Radar Experiment

> Finally, it is recommended to conduct a follow-up study to enable the evaluation of the effectiveness of photo radar. It is recommended that efforts are made to improve data collection to enable the evaluation of this aspect of the program.

# 1. INTRODUCTION

The Traffic Injury Research Foundation (TIRF) was contracted by the City of Winnipeg to evaluate the Winnipeg photo enforcement safety program of the Traffic Safety Unit of the Winnipeg Police Service. The evaluation project began in the spring of 2008. This final report contains the results of the evaluation project.

## 1.1 Objectives

The objective of this project is to evaluate the Winnipeg photo enforcement safety program. The components of the evaluation include:

- a review of the literature about photo enforcement;
- a process evaluation of Winnipeg's photo enforcement safety program;
- a public opinion poll in Winnipeg about the photo enforcement safety program;
- an analysis of the effect of photo enforcement on traffic safety in the municipality, including annual statistics and year to year variances in:
  - traffic collisions;
  - traffic injuries; and,
  - collision severity;
- a controlled study evaluating the impact of photo enforcement at intersections on speed and red light violations; and,
- a controlled study evaluating the impact of mobile photo radar on speed at schools and construction sites — note that due to data limitations it was not possible to carry out this component of the evaluation project; this is explained in more detail in section 7 of this report.

## 1.2 Overview

TIRF has developed a multifaceted and versatile approach for this evaluation using roadside survey data, collision data, public opinion data, and process evaluation data. The report is divided into separate sections containing a literature review, a process evaluation, a public opinion poll and an outcome evaluation that includes time series analyses, an intersection camera experiment and a photo radar experiment.

First, a review of the literature regarding speeding and red light running was conducted and is presented in Section 2 of this report. This review included a thorough examination of enforcement strategies and other traffic management strategies including photo enforcement cameras. Studies on the effectiveness of photo enforcement programs were reviewed as well as studies challenging the effectiveness of photo enforcement. The costs and benefits of such programs are also presented as well as literature pertaining to public support for such programs.

Section 3 of this report presents the findings of the process evaluation component of the study. The overall objective of the process evaluation is to document the development and implementation of Winnipeg's Photo Enforcement Safety Program, and to explore the experiences and perspectives of participants that were involved in this process. The goal is to increase understanding of the program and provide insight into what strategies have worked well, where challenges or gaps (if any) occurred, and identify potential areas for improvement. Information about the implementation of the program and how it has been/is being delivered was collected in 2010 through in-depth interviews with key people involved in the project. A wide variety of relevant documents pertaining to the program were also reviewed as part of the evaluation to provide additional detail about key program components, strategies and challenges. Recommendations based upon the outcomes of the process evaluation of Winnipeg's photo enforcement program are presented and discussed in this section.

Public attitudes towards speeding and red light cameras can have a significant influence on the success or failure of these programs. Although drivers may reduce their speed and obey traffic signals in order to avoid apprehension, negative public attitudes may counteract the immediate benefit and even inspire defiance of traffic laws. Thus, when evaluating the success of a photo enforcement program, it is essential to understand public attitudes towards these programs. A public opinion poll was conducted among residents within the Winnipeg Central Metropolitan Area (CMA) in May 2009 as part of this evaluation and is described in Section 4 of this report. The public opinion poll examined both the knowledge and opinions of drivers with respect to Winnipeg's photo enforcement program using appropriate statistical methods.

Time series analyses were performed to investigate the effects of Winnipeg's Photo Enforcement Safety Program on crashes. Results from these analyses are presented in Section 5 of this report. Such data provide insight into trends regarding collisions, injuries and crash severity before and after the implementation of photo enforcement in Winnipeg. Winnipeg collision data were used to develop a database containing time series of monthly collision counts from 1994 through 2008 in Winnipeg. These data are used in the time series analyses along with control group data from New Brunswick.

For the intersection camera experiment portion of the study, roadside data on speeding and red-light running behaviour were collected to examine the effect of the intersection safety cameras. These results are presented in Section 6 of this report. For the purposes of this study, sites that are comparable to already-existing enforcement sites of the program, but at which photo enforcement had not yet been deployed were chosen for this component of the evaluation. A quasi-experimental evaluation design with experimental and control groups was used to determine whether the implementation of the intersection safety cameras led to fewer drivers who speed and/or run red lights. These data were analyzed using appropriate statistical methods.

The mobile photo radar experiment is described in section 7 of the report. As mentioned previously, it was not possible to conduct any analyses about the effectiveness of photo radar due to data limitations. Reasons for this are explained in more detail in section 7.

Finally, overall conclusions and recommendations coming from each component of this evaluaiton are described in sections 8 (conclusions) and 9 (recommendations).

# 2. LITERATURE REVIEW

## 2.1 Background

Speeding and red light running are among the leading causes of road crashes in Canada and the United States (Goldenbeld and Schagen 2005; McGee and Eccles 2003; Tay 2000). According to Kloeden et al. (2001), driving above the speed limit increases one's risk of crashing, injury, and death. Likewise, red light running also increases the risk of crashing, injury, and death for obvious reasons. The consequences of speeding and red light running vary in magnitude. Generally, as speed increases, so does the risk of being involved in a collision as well as the severity of that collision (Evans 2006; Hess 2004; Elvik 2005). In fact, the risk of being involved in an accident increases proportionately to the increase in speed. Increasing the average driving speed by as little as 1% raises the risk of fatality by 4-12% (Evans 2004); driving 10 km/h above the speed limit more than doubles the risk of being involved in an accident (Kloeden et al. 2001), while driving 20 km/h above the limit increases this risk up to six times. Of importance, a large meta-analysis involving 98 studies concluded that "The relationship between speed and road safety is robust and satisfies all the criteria of causality commonly applied in evaluation research…Speed is likely to be the single most important determinant of the number of traffic fatalities" (Elvik 2005, p.69). In addition, large differences in speed between moving vehicles (speed dispersion) on a roadway is also related to crash rate as a vehicle that is moving much faster than surrounding traffic has a higher crash rate (Aarts and van Schagen 2006).

Moreover, the collisions that result from red light running also vary in severity. Red light running generally results in right-angle collisions which have a higher injury and fatality rate than most other types of collisions, including rear-end collisions (Helai et al. 2008). In the United States the cost of red light running collisions alone has been estimated to exceed $14 billion per year (Blakey 2003).

In Canada, excessive speeding has been identified as a contributing factor in up to 18% of crashes (Beirness and Simpson 1997). This corresponds to approximately 4,000 deaths and injuries each year that are attributable to excessive speed (Beirness et al. 2001). Also, red light running is responsible for more than one quarter of all traffic injuries at intersections with traffic lights (Brault et al. 2007). According to an Ontario study (Ministry of Transportation Ontario 1998), disobeying traffic signals is involved in 42% of fatal crashes and 29% of injury crashes. Therefore, approximately 61 fatal crashes and 4,800 injury crashes occur in Ontario each year as a result of drivers running red lights. Traffic enforcement is one way to help reduce the incidence and severity of speeding and red light running. In the following sections an overview is given of relevant enforcement technologies.

## 2.2 Enforcement Strategies

The goal of police speed enforcement is to improve road safety. Before radar guns and other new technologies became available, police relied on traditional methods for managing and enforcing speed limits. As early as 1910, law enforcement officers in Massachusetts began using a camera synchronized with a stopwatch to record speeding vehicles. The speed of vehicles was determined using mathematics to measure the reduction in size of the motor vehicle in the picture (Teigan 2010). Another method was known as the time-distance method in which police officers would hide in dummy tree trunks and record the time at which a car passed (Lynn et al. 1992). This time in combination with the travelers' distance was used to compute the speed. The time-distance method evolved into the stopwatch method which employed the same principle but involved a device consisting of two rubber tubes that were stretched across the road at a certain distance apart. Each tube was connected to a switch that would trigger a stopwatch. In a similar manner, the electric timers were triggered at point one and point two and the speed was then calculated. This method further evolved into the Visual Average Speed Computer Recorder (VASCAR), a computerized system that computes a car's speed by examining the time it took to travel the distance between two fixed markers (Lynn et al. 1992).

Pacing is another method used by police. Pacing refers to the method in which police officers follow a vehicle for a certain distance and observe their own speedometer over this distance. The speed is then averaged and the police officers are able to determine whether or not the vehicle was exceeding the speed limit (Lynn et al. 1992).

Then, in the early 1950's, police radar was introduced (Lynn et al. 1992). Police radar transmits waves that reflect off of a moving vehicle and return with a shifted frequency.

The radar device measures the shift in the original frequency in order to compute the vehicle's speed. More recently, radar technology has been combined with camera technology. When the radar detects a speeding vehicle it is able to trigger the camera in order to photograph the violating vehicle. The available technology and use of these cameras vary considerably. Some cameras are only capable of capturing the licence plate number while others are able to photograph the face of the individual driving the vehicle. This has implications for enforcement as it determines the ability to issue tickets to the actual offender as opposed to the registered owner of the vehicle, who may or may not have been the driver of the vehicle at the time of the offence.

The effects of police enforcement in reducing traffic violations have been widely studied. Generally, the reviews of these studies are positive. Most studies suggest that enforcement and the issuing of tickets alter driving behaviour, thus reducing the number of violations and associated crashes. This has been found to be the case particularly for speed enforcement (Pilkington and Kinra 2005; Zaal 1994; McCarthy 1991).

Nevertheless, enforcing violations for drivers that disregard traffic signals is not an easy task. Police enforcement requires significant manpower and costly resources that are usually unavailable. This lack of resources can result in inadequate enforcement. To illustrate, a review of the evidence by Ostvik and Elvik (1991) concludes that the effect of stationary police enforcement is local and the magnitude of the effect varies according to time and space but is typically small. Halo effects of such enforcement measures range from a few hours to several weeks depending on the intensity of enforcement (Sisiopiku and Patel 1999; Vaa 1997). In order to increase the subjective risk of detection, to reduce the number of offenders and reduce the number of crashes by 10-20%, the level of enforcement must be increased by at least three times over previous levels; an increase smaller than this has little or no effect on these factors. This occurs because drivers cannot perceive small differences in the actual risk of detection and cannot be led to believe that enforcement has increased when it has not (Ostvik and Elvik 1991).

Even when police resources are available, enforcement can be dangerous often requiring police officers to chase the violating vehicle endangering nearby motorists, pedestrians, and of course the police officer him/herself (Delaney et al. 2005). As such, Herbert Martinez and Porter (2006) conclude that "inconsistent or improbable enforcement is not likely to be a cost-effective, long-term solution to red light running" (p.863).

In light of the positive and proven effects of speed enforcement, safer and more time and cost efficient enforcement strategies have been sought. Photo enforcement cameras are an example of one promising technology that has been developed in order to reduce speeding and/or red light running in a cost efficient way — these programs and their effectiveness are discussed in subsequent sections of this literature review.

## 2.3 Other Traffic Management Strategies

It is important to note that there are a variety of other traffic management strategies that can also reduce speed. These include Intelligent Speed Adaptation (ISA), speed calming measures, public awareness programs, and intersection design, among others. ISA systems are in-vehicle devices with the capacity to either warn against or limit speeding (Arhin et al. 2007). The less controversial warning informational ISA systems have the capacity to warn drivers against exceeding speed limits. This form of ISA is generally much less effective in comparison to the limiting ISA system which has the capacity to take control of the gas pedals inside the vehicle in order to limit and regulate speed. While more effective, these systems are highly controversial and generally face strong resistance (Arhin et al. 2007).

Speed calming measures, otherwise known as speed bumps, is another strategy used to manage speed. Speed bumps consist of raised surfaces stretched across the road in an attempt to slow traffic. These raised surfaces require that vehicles substantially reduce their speed before passing over them. Speed bumps have been demonstrated very effective in reducing speed (Corkle et al. 2002) and are also very cost efficient to implement. Nevertheless, concerns have been raised regarding the potential damage they may cause to vehicles as well as to the environment. Although speed bumps have evolved in order to cause the least amount of damage to cars that slow down enough before passing over them, there are still environmental concerns that arise due speed bumps. Accelerating after a speed bump generates significantly more pollution than would occur if speed was maintained more or less constant, which would be the case without speed bumps.

Public awareness is yet another way of managing speed. Public awareness programs, such as the Speed Management program of Manitoba Public Insurance (MPI), attempt to reduce speeding by increasing public awareness of the problem (Manitoba Public Insurance 2009). Public awareness programs on speeding and red light running aim to create long term changes in drivers' attitudes and behaviours through education and raising awareness about the dangers of disobeying these traffic laws. Research shows that public awareness is often more effective when used in synergy with enforcement techniques (Chen et al. 2000; Delaney et al. 2005).

Delaney et al. (2005) report that there are some common debates that frequently arise in many jurisdictions when speed cameras are implemented, including: fine revenue; fairness (driver identification and immediate notification); people do not believe moderate speeding increases crash risk; reliability of cameras; and, privacy. The study reports that it is essential that public awareness programs address these issues. These controversies are generally addressed by: targeting high crash locations; strong and consistent education and awareness efforts; making enforcement visible to drivers; and limiting the role of camera vendors.

With regard to red light running, managing and reducing violations can often be achieved by improving intersection design. According to Blakey (2003), engineering is a very important part of any traffic management program. Engineering countermeasures are designed to minimize the likelihood that drivers are in a situation where they must make a decision whether or not to commit the violation (Bonneson and Zimmerman 2004). Making changes to improve intersection design can significantly reduce red light running and its associated crashes (Blakey 2003; Retting et al. 2008b). For example, in Detroit, Michigan city officials were concerned that crash rates in Detroit were double the crash rates in the rest of southeast Michigan. To address this problem, city engineers installed larger lenses on traffic lights, made left turn lane markings more visible and re-timed traffic signals. In addition, better signs and pedestrian signals were also added. As a result, crashes were reduced by 47% and injuries were reduced by 50% in the first 27 months of the four demonstration programs; a 50% reduction in red-light running was also reported. It was suggested that these types of improvements are particularly effective with drivers who tend to run red lights because they are distracted as opposed to being aggressive (AAAFTS 1999). Blakey (2003) has suggested the following improvements in order to reduce red light running: ensuring that the length of the yellow light phase is adequate, that there is adequate signal brightness, that there is coordinated signal timing, and that there is use of advance signal warning signs.

Research that examines the timing of the yellow light phase shows that, while this countermeasure is effective at reducing red light violations, it has a smaller effect on reducing red light crashes as drivers will alter their stopping behaviour to offset the effect of a longer light change interval (Bonneson and Zimmerman 2004). According to the results of this Texas study, “an increase of 1 second in yellow duration (provided it does not exceed 5.5 seconds) will decrease the frequency of red light violations by at least 50%” (Bonneson and Zimmerman, 2004; p,20). This study used a before-after design to examine how drivers responded to a longer yellow light interval and confirmed that drivers do adapt to the longer yellow light interval, noting that this adaptation did not negate the advantage associated with longer yellow signal periods.

A larger study by Retting et al. (2002) also examined the yellow light timing interval across 40 sites in New York and found an 8% reduction in reportable crashes at experimental sites as compared to crashes at control sites in the three year period following signal timing changes. In addition, there was a 12% reduction in injury crashes at experimental sites as compared to control sites. However, the authors caution that this countermeasure will not reduce crashes that occur due to the unintentional running of red lights that are a result of inattention or other driver failures that may occur long after the light has turned red.

A 2008 field study conducted by Retting et al. (2008b) in Philadelphia directly compared the effects of a longer yellow signal timing and red light camera enforcement to determine their respective effects on red light running. The study examined the incremental effects that were accrued by first extending the yellow light timing and then followed by the implementation of red light cameras. The findings revealed that the extended yellow light period was effective in reducing red light running by 36%. The inclusion of red light camera enforcement resulted in further reductions of 96% beyond the levels achieved by the lengthening of the yellow light. The results of this study demonstrate that an adequate yellow light interval reduces red light running but does not mitigate the need for consistent enforcement that can be achieved by photo enforcement. The study concludes that “Overall, the results from the present study confirm that providing motorists with adequate yellow signal timing is important for reducing red light running. However, even with proper yellow timing in place, red light running remains a problem that can be further reduced through the use of camera enforcement” (Retting et al. 2008b; p.332).

Finally, research shows that converting traditional intersections into roundabouts can reduce the number of injury and fatal crashes (see e.g., Daniels et al. 2010; Federal Highway Administration 2000; Persaud et al. 2001). However, such an infrastructure measure is associated with a high cost and not all intersections are suitable for conversion into a roundabout.

## 2.4 Photo Enforcement Cameras

As previously mentioned, photo enforcement devices such as speed cameras and/or red light cameras are increasingly being used in addition to standard police enforcement techniques in an attempt to reduce speeding and red light violations in an efficient fashion. The goal of photo enforcement is two-fold: red light and speeding cameras are used in an attempt to reduce both speeding and red light running and in so doing reduce the number of crashes associated with these traffic violations.

Photo enforcement cameras are designed to automatically photograph vehicles that pass through the intersection after the light has turned red and/or at speeds surpassing the indicated speed limit. Enforced intersections are equipped with sensors below the pavement at the designated stop line. These sensors are connected to cameras that continuously monitor the traffic signals. If a vehicle passes over the sensors at a certain speed and/or at a certain elapsed period after the light has turned red, the camera will be triggered. The camera records all necessary information: date, time of day, time elapsed since the beginning of the red light signal, as well as the speed of the vehicle. After reviewing the evidence a ticket is issued, usually to the registered owner of the vehicle.

Although results vary considerably by study, photo enforcement is generally believed to bring about significant behavioural changes in motorists that result in reduced disregard for traffic signals and designated speed limits (Blakey 2003).

## 2.5 Effectiveness of Photo Enforcement Programs

There is considerable variation in the literature regarding the effectiveness of photo enforcement programs. While most studies find an overall reduction in speeding, red light running, and associated crashes, some studies fail to find any significant improvement (e.g., Andreassen 1995; Burkey and Obeng 2004) or find results that suggest photo enforcement is effective only at some locations or under certain conditions. These latter studies conclude that more research is needed to better understand the impact of photo enforcement and how this measure can best be employed (e.g., Garber et al. 2007; Erke 2009; Kent et al. 1997).

In general, photo enforcement is expected to reduce speed associated collisions and decrease right-angle collisions at intersections while increasing rear-end collisions (Aeron-Thomas & Hess 2005; Decina et al. 2007; Blakey 2003; Shin et al. 2009; Council et al. 2005; Shin and Washington 2007; Ministère des Transports Quebec 2010). For example, Council et al. (2005) found a 15% increase in rear-end collision concurrence and a 25% decrease in right-angle crashes (Council et al. 2005). However, right-angle collisions have a higher injury and fatality rate than rear-end collisions (Helai et al. 2008), so there is generally a net benefit in terms of lives saved and serious injuries prevented as well as a crash-cost benefit (Council et al. 2005).

A recent systematic review of speed cameras for the prevention of road traffic injuries and deaths published by the highly regarded Cochrane Collaboration that specializes in systematic reviews concluded that "…the consistency of reported reductions in speed and crash outcomes across all studies show that speed cameras are a worthwhile intervention for reducing the number of road traffic injuries and deaths" (Wilson et al. 2010: p. 2). This study analyzed results from 35 studies that met the inclusion criteria and found reductions in average speed ranging from 1% to 15% and reductions in proportion of vehicles speeding ranging from 14% to 65%. Furthermore, they report that near camera sites pre-post reductions ranged from 8% to 49% for all crashes and 11% to 44% for fatal and serious injury crashes. In comparison with controls, the relative improvement in pre-post injury crash proportions ranged from 8% to 50%.

An earlier report by Decina et al. (2007) concluded that key studies reported significant reductions in speed related crashes although cautions that only a few studies were well-controlled. Pilkington and Kinra (2005) reviewed the literature on speed cameras and reported that reductions in crash rates vary between 5% and 69% with a 12% to 65% reduction in injury crashes, and 17% to 71% reduction in fatality crashes. This demonstrates great variability in the findings on the effectiveness of photo enforcement.

A synthesis of the evidence published by the Transportation Research Board in 2003 (McGee and Eccles) concluded that there was a preponderance of evidence showing that red light running cameras improve the overall safety of intersections where they are used. The 2003 report stated, however, that the evidence was not conclusive.

Regarding red light running behaviour, one systematic review supports the conclusion that photo enforcement leads to a reduction in right-angle crashes as well as an increase in rear end crashes (Decina et al. 2007) and recommends further research. Another systematic review by the Cochrane Collaboration concludes that red light cameras are effective in reducing total casualty crashes but the evidence is less conclusive about total crashes, specific collision types and violations (Aeron-Thomas and Hess 2005).

A 2008 research note by Obeng and Burkey, examined whether offsetting driver behaviour affects rear end crashes at intersections with red light cameras. It revealed that, “in the city considered, the effect of red light cameras on the probability of rear end crashes occurring is very strong and positive, thus suggesting that offsetting behavior is present” (p.811). Authors caution that limitations of the study design fail to account for changes in other types of crashes (notably decreases in right angle crashes) and that the generalization of these results to other cities may not be appropriate. Also, this study did not investigate whether such offsetting behaviour is time dependent and dissipates as time goes by and drivers become accustomed to the presence of photo enforcement cameras.

Additionally, while some studies find that photo enforcement works to reduce traffic violations at the camera sites alone, other studies suggest there is a spill-over or halo effect, i.e., a reduction in surrounding non-camera intersections as well. For example, in Ontario there was an overall decrease in speeders after introducing a photo enforcement program and this reduction held true for both enforced areas and surrounding areas (Ministry of Transportation 1995). This spillover effect suggests a more generalized change in driving behaviour. Other studies on the effectiveness of photo enforcement in Fairfax Virginia, Oxnard California, British Columbia (BC), Scottsdale Arizona, and Cambridgeshire, UK also found evidence of spillover effects (Retting and Kyrychenko 2002; Retting et al. 1999; Chen et al. 2000; Shin and Washington 2007; Hess 2004), while no spillover effects were found in Phoenix, Arizona (Shin and Washington 2007). Further, it is noted that “spillover or distance halo effects are a key advantage of automated speed enforcement that are not generally achieved by traditional police speed enforcement" (Retting et al. 2008a, p. 444).

The variation in the results across these studies can be explained by several factors. To begin, the size of the program will determine the magnitude of the benefits. In other words, the larger the program is, the larger the benefits will be (Cameron 2003). Therefore, comparing programs of different sizes will inevitably produce varied results. Another issue involves the use of public awareness campaigns as part of photo enforcement programs. Studies that raise public awareness before the implementation of the program arguably have better results since this raised awareness helps compel drivers to reduce their speeds and obey traffic signals in order to avoid apprehension. For example, a study by Chen et al. (2000) on a photo enforcement program in BC found that 95% of insured vehicle owners knew of the program before its introduction. As a result, the proportion of speeding vehicles decreased by 50% in 7 months. The program also reduced the mean speed at enforced sites by 2.4 km/h. The reduced speeds associated with the program coincided with a significant 17% reduction in traffic collision fatalities. Similarly, a study in Maryland by Retting et al. (2008a) reported that highly visible automated enforcement can result in reductions in speeding beyond targeted locations.

Furthermore, most of these studies also varied in terms of their research design and methodology. According to a meta-analysis conducted by Erke (2009) examining 21 studies on the effects of red light cameras (RLCs) on the incidence of intersection crashes, the effectiveness of photo enforcement varied considerably according to study methodology. Reliable evaluation is critical and researchers must consider and control for confounding factors that can impede this (Sayed and de Leur 2007). Most of the studies examining the effects of photo enforcement have at least one of two common methodological flaws: failing to control for spillover effects and/or failing to control for regression towards the mean (RTM).

The first methodological problem occurs when studies examining the effects of photo enforcement programs compare crashes at camera equipped signalized intersections with other “control” intersections without cameras but within the same jurisdiction. Nearby signalized intersections cannot serve as adequate controls because there is typically a halo effect of camera enforcement at non-camera sites (Erke 2009) – as described previously, such effects were observed in several jurisdictions including Virginia, California, British Columbia, Arizona and the UK. Crash reductions estimated by comparing camera with non-camera sites therefore are likely to underestimate the effect of cameras on crashes. This is known as not adequately controlling for spillover effects.

The second methodological problem occurs when sites chosen for camera enforcement are not chosen at random. The sites used for photo enforcement are usually chosen because they had an especially high number of crashes. It has been demonstrated that extreme values in a distribution, such as a particularly high number of crashes in an area during one time period, will tend to move toward the average of the entire group of such areas (i.e., decrease) in the succeeding time period even if nothing is done to affect the crashes (Campbell and Stanley 1966). This phenomenon, recognized for years by statisticians and researchers in many fields is known as regression towards the mean (RTM). Such RTM can result in an overestimation of the effects of camera enforcement on crashes (see e.g., Jones et al. 2008 and Brenac 2010). Choosing comparison sites with similar characteristics can partially, but not fully, address this problem. Statistical techniques have been developed for estimating and adjusting for RTM individually at each site (see Hauer 1997). Alternatively, time series analyses can be used to account for pre-existing trends and disruptions to such trends over longer periods of time when analyzing monthly crash counts (see e.g. Novoa et al. 2010). However, such techniques were not employed in most of the studies examined in Erke’s meta-analysis.

Consequently, Erke (2009) argued that if a study does not control for RTM it will overestimate the positive effects of photo enforcement, and that if it does not control for spillover effects it will underestimate the positive effects of photo enforcement. According to Erke’s meta-analysis, the few studies that did properly control for RTM and spillover effects only found a slight reduction in right-angle crashes (up to 10%) and a significant increase in rear-end collisions (up to 40%), resulting in an increase in overall crashes (up to a 15%) as a result of photo enforcement. This led the author to conclude that although enforcement cameras "may reduce crashes under some conditions, on the whole [they] do not seem to be an effective safety measure" (Erke 2009).

Although the meta-analysis performed by Erke (2009) concluded that photo enforcement cameras "do not seem to be a successful safety measure", the method with which this conclusion was drawn has been criticized. It has been argued that although Erke provided a meta-analysis of various red light camera studies, she did not provide a critical review of these studies. As Lund et al. (2009) have stated meta-analysis is a very powerful statistical procedure that entails a certain scientific authority. Nevertheless, this authority is misleading when other key factors are omitted. Lund et al. (2009) argue that Erke did not critically evaluate the variety of the studies used and whether these studies were designed to adequately address the research question. Instead, Erke obtained her analysis by combining various studies that were not "comparable enough in nature to justify averaging them" (Lund et al. 2009: 895). In addition, Erke claimed that the main studies included in her analysis adequately measured for RTM and spillover effects, when in fact some estimates of the effects of red light cameras came from comparisons with control sites that were in the same jurisdiction as the camera intersections and therefore did not have the ability to control for spillover effects. The use of a combination of well-controlled and "questionable studies" reduces the validity and accuracy of Erke's meta-analysis. In sum, this study has been criticized for relying solely on advanced mathematical techniques instead of providing a systematic and critical review. Thus, the results are less authoritative than they appear (Lund et al. 2009).

A third methodological problem that is associated with some studies is the reliance on total crashes in lieu of target crashes. Results of these studies "may be biased because total crashes in lieu of target crashes (crashes that are materially affected by the photo enforcement speed cameras) were examined. As a general result, the use of total crashes instead of target crashes will lead to inaccurate estimates of safety impacts". (Shin et al. 2009, p. 394). In other words, these authors argue that evaluations should not rely on data from crashes that cannot be prevented by photo enforcement. For example, crash data from all crashes would include alcohol related crashes and photo enforcement will most likely not affect such crashes at all. Therefore it is logically more sound to use counts from types of crashes that are targeted or affected by photo enforcement such as right angle and rear end crashes.

## 2.6 Studies that Challenge the Effectiveness of Photo Enforcement

There are three main studies that are often cited by opponents of photo enforcement to support their position. These studies report findings that are not entirely consistent with other studies and question the safety benefits of photo enforcement. These studies are described in more detail below.

The first study was conducted in Virginia by Garber et al. (2007) and examined crashes at 30 intersections in six communities in northern Virginia. Results of the study were mixed: increases in all six types of crashes that were part of the study were reported in some communities whereas other communities showed decreases in most crash types. It is interesting to note that this study did not recommend abolishing photo enforcement altogether; rather, its main recommendation was to carefully select locations when installing photo enforcement cameras and to further investigate how this measure can best be used, a recommendations also made previously by Washington and Shin (2005). Nevertheless, the study was critically reviewed by Persaud et al. (2008) who noted several methodological issues, including problems with the application of the Empirical Bayes method, weak crash prediction models, inappropriate comparison sites, gaps in traffic volume data on minor roads and the potential for reporting bias due to the definition of red light running crashes. Lund et al. (2009) further noted that the Garber et al. (2007) study failed to control for spillover effects or regression to the mean. Persaud et al. (2008) concluded that the Virginia study contained "significant methodological issues [with the VTRC study] that call into question the validity of its conclusions" (p.1).

A second study conducted in North Carolina by Burkey and Obeng (2004) was designed to estimate the crash reduction or increase, if any, associated with red light cameras. Results of the study showed that red light cameras are associated with 42% more crashes and also question the safety benefits of red light cameras. A critical review of this study by Kyrychenko and Retting (2004) identified methodological flaws that invalidated the conclusions drawn from the study. These flaws included a failure to control for regression to the mean or for spillover effects. More importantly, in their critical review of this study, Kyrychenko and Retting (2004: p. 2-4) show that Burkey and Obeng's approach of analyzing the data was flawed because they allegedly failed to account for the fact that baseline crash levels before the installation of crashes differed across experimental and control sites — a critique that has later been contested by Burkey and Obeng (see Burkey's rebuttal published in 2005). The critical review by Kyrychenko and Retting (2004) of this study by Burkey and Obeng also included a rebuttal to Burkey and Obeng's criticism of Kyrychenko and Retting's Oxnard, California study.

While the resolution to the ongoing debate between Kyrychenko and Retting on one hand and Burkey and Obeng on the other is well beyond the scope of this review, it does clearly illustrate the challenges associated with the development of a rigorous methodological design that can effectively evaluate photo enforcement programs. There are a wide range of complex and technical issues that must be considered as part of any evaluation plan, hence the ability to replicate or re-produce study findings, as well undergo a peer-review process are of paramount importance to validate study conclusions. In this regard, there are now several systematic reviews of the literature available (see e.g., Wilson et al. 2010; Aeron-Thomas & Hess 2005; Decina et al. 2007; Pilkington and Kinra 2005; McGee and Eccles 2003) and these reviews lend credence to the available evidence. Furthermore, in a peer-reviewed study Obeng and Burkey were able to confirm their earlier findings regarding increases in rear end crashes at intersections with cameras but caution that generalizing their results may not be appropriate and that it is possible that reductions in other types of crashes, notably right-angle crashes are more than the increases in rear end crashes (Obeng & Burkey 2008: p. 816).

As a sidebar, a study by Langland-Orban et al. (2008) also questions the safety benefit of red light running cameras and uses the studies by Burkey and Obeng (2004) and Garber et al. (2007) to suggest a conspiracy theory stating that the insurance industry supports photo enforcement in the face of evidence showing that it leads to increases in crashes. These authors argue that "more crashes lead to higher insurance premiums, leading to higher profits, which in turn lead to increases in insurance stock prices." (2008: p.4) and suggest this is the reason why insurers support photo enforcement cameras as a safety measure. However, the authors fail to explain how such pricing models would indeed lead to more profits. For example, one could easily argue that more crashes also imply more claims, which would detract from higher profits. In sum, while it is indeed important that photo enforcement is used to increase safety rather than generating revenue, these authors do not provide any evidence to substantiate these allegations about the insurance industry's hidden agenda regarding photo enforcement. Also, they build their argument on a few studies that challenge the effectiveness of photo enforcement but fail to acknowledge the many studies that support the use of photo enforcement.

In an update of their work published in 2011, Langland-Orban et al. (2011) further discuss controversies related to photo enforcement and conclude that proper intersection engineering is required prior to consideration of photo enforcement. While the traffic safety research community endorses such an approach, Langland-Orban et al. fail to provide a balanced description of the research about the effectiveness of photo enforcement in their update, especially of those studies that are most controversial. For example, one of the studies that is often cited by opponents of photo enforcement is the previously discussed study by Garber et al. (2007). Results of this study are used by opponents of photo enforcement to recommend abolishing photo enforcement altogether, which is not supported nor recommended by Garber et al. In fact, Garber et al. did find positive effects of photo enforcement but none of these are mentioned by Langland-Orban et al. in their update (2011). Langland-Orban et al. also emphasize the weaknesses of studies with results supporting photo enforcement but fail to acknowledge that studies with results that question the positive impact of photo enforcement often suffer from comparable weaknesses.

Finally, as one last example of some challenges with this update, Langland-Orban et al. (2011) do not appreciate the fact that, statistically speaking, numbers really can be too low for any meaningful analysis. For example, they critique exclusion of fatal crash counts in some analyses as well as the use of intermediate measures such as violations rather than crashes. However, both excluding fatal crash counts when they are too low and, hence, statistically unstable, as well as using proxies such as violations in lieu of crashes (because crash counts are either not available or too low) is an approach that is widely adopted and accepted in traffic safety research and has been used to produce supporting evidence for many other safety measures. In sum, both the 2008 and the 2011 papers by Langland-Orban et al. singled out a few studies that question the effectiveness of photo enforcement but fail to acknowledge the convergence of evidence that, generally speaking, does show a positive impact of photo enforcement. The value of their work lies in the attention they draw to the potential misdirected use of photo enforcement as a revenue generator rather than a way to increase traffic safety to the benefit of the public. Also, they do corroborate and reiterate the importance of carefully selecting sites suitable for photo enforcement.

The third study that questioned the safety benefits of red light cameras was the before-mentioned meta analysis conducted by Erke (2009). It is noted that two of five studies used in the meta-analysis were Garber et al. (2007) and Burkey and Obeng (2004). These studies were given much weight in Erke's meta-analysis, which explains the biased results from this study.

## 2.7 Costs and Benefits

In addition to the positive effects of photo enforcement programs described in the previous paragraph, the savings associated with these programs often exceed the costs, even though photo enforcement programs can be expensive to implement and lead to increases of rear end crashes. For example, while Calgary’s photo enforcement program cost over two million dollars to implement, they estimated a total savings of more than twenty million dollars. After factoring in the savings from reduction in enforcement costs as well as a reduction in the costs associated with road collisions, the Calgary study reported saving approximately eleven dollars for every dollar spent on their program (Project Summary Report 2005).

Societal savings such as this have been experienced in many other programs. A study examining photo enforcement in Fairfax, Virginia found that the reduction in crashes that resulted from their photo enforcement program saved nearly thirteen million dollars over eight years (Retting et al. 1999). Likewise, the total estimated benefit of the speed enforcement program in Scottsdale, Arizona was approximately seventeen million dollars per year (Shin and Washington 2007). A 2005 study that analyzed data from seven jurisdictions by Council et al. concluded that red light cameras “do indeed provide a modest aggregate crash-cost benefit of between $39,000 and $50,000 per treated site per year, depending on the consideration of only injury crashes or including property damage only crashes". Finally, a Norwegian study reported a benefit/cost ratio for speed cameras of 2.11[1].

Most recently, a study by Hu et al. (2011) investigated the effects red-light cameras on per capita fatal crash rates at signalized intersections in 99 large U.S. cities with more than 200,000 residents. They examined two separate study periods (1992-1996; 2004-2008) and compared the citywide per capita rate of fatal red light running crashes and the citywide per capita rate of all fatal crashes at signalized intersections. The rate changes were then compared to cities with and without cameras. Study results showed that "camera programs were associated with statistically significant citywide reductions of 24% in the rate of fatal red light running crashes and 17% in the rate of all fatal crashes at signalized intersections, when compared with rates that would have been expected without cameras" (Hu et al. 2011; p.8). The authors do discuss some limitations of the study and the data used. Despite these limitations, the Insurance Institute for Highway Safety used these results to estimate that a total of 815 lives would have been saved if cameras had been operating in all cities with a population larger than 200,000 between 2004 and 2008 (IIHS 2011).

These savings help to fund the maintenance of photo enforcement programs and result in the continued reduction in crashes, injuries, and deaths. Also, profits from these programs can be diverted to support other programs that benefit the public.

## 2.8 Public Support

Public support for photo enforcement strategies is critical to the success of these programs. In many jurisdictions where photo enforcement has been implemented, research shows that levels of public support have been high prior to and post-implementation. These high levels of support have contributed to efforts to expand the use of cameras in some jurisdictions.

[1]http://www.erso.eu/knowledge/content/08_measures/promising_road_safety_measures_based_on_cost_benefit_analyses.htm

[2] It warrants mentioning that extensive efforts were made to obtain monthly counts of such variables as

Measures of public support in the United Kingdom shows that a majority of drivers (75-80%) are in favour of the use of speed cameras and that this high level of acceptance has been consistent over time even though the program has grown and more drivers have had personal experience with citations. The program has expanded from 21 speed cameras in 1992 up to an estimated 4,500 safety camera sites on British roads by 2000 (Delaney et al. 2005). Of interest, cameras in the United Kingdom are conspicuous and highly visible to drivers.

In Victoria, Australia, even though the use of cameras has been covert (e.g., a variety of unmarked cars and flashless cameras) there are similar levels of support for speed cameras. Public opinion polls reveal that about 80% favoured camera use in 1991 when the program was implemented, and that support for cameras remained high even after the program was expanded from 4,200 hours of camera operation per month to over 6,000 hours and strengthened by lowering speed thresholds. The average number of citations per month was 40,000-50,000 per month in 2001-2002; this peaked at 96,000 in 2003 and has since declined as driver behaviour has changed (Delaney et al. 2005). The levels of public support for speed cameras that are evident in North America have been somewhat lower (55-60%) than those achieved in Victoria and Britain. It has been suggested that this difference may be a result of stronger privacy concerns in North America, which have also similarly affected the implementation of the stronger drink driving and seatbelt enforcement measures used in Australia. Indeed, some polls in North America have reported a smaller majority support speed cameras with a not insignificant minority voicing opposition. As evidence of this, a 2004 national telephone survey of 886 drivers conducted by the Insurance Institute of Highway Safety revealed that 54% (32% strongly in favor; 22% somewhat in favor) supported speed camera use; 43% (15% somewhat opposed; 28% strongly opposed) opposed camera usage to varying degrees (Delaney et al. 2005).

More recently, a study conducted by the U.S. Insurance Research Council in 2007 reported that 70% of the public (39% strongly; 31% somewhat) supports red light cameras. With regard to speed cameras, 60% (31% strongly; 29% somewhat) of the public are supportive of this countermeasure. These 2007 figures have increased since 2001 when earlier polls reported 65% supported red light cameras and 52% were in favour of speed cameras (IRC, 2007).

Most recently, an Ontario survey conducted by Harris/Decima in November 2010 on behalf of the Ontario Road Builders Association (ORBA) reported that 67% of respondents supported the use of safety cameras to measure speed near schools, community centres and construction zones on provincial highways and local roads. The highest levels of support (75-80%) were associated with retirees and women. In addition, survey results showed that a clear majority (76%) agreed that tackling aggressive drivers should be a priority for the Ontario government (ORBA 2010).

Of note, the results of public opinion polls about photo enforcement in other jurisdictions are very consistent with poll results reported in Winnipeg. A May 2009 poll of Winnipeg residents revealed that about 80% were concerned about drivers who run red lights; 60% expressed high levels of concern about speeding. And, 71% of residents agreed that Winnipeg's photo enforcement program helped improve road safety in Winnipeg and a clear majority (81%) supported the continuation of the program — see the section entitled "Public Opinion Poll" in this report for more detailed information.

## 2.9 Summary

The methodological limitations associated with earlier and a few more recent studies (i.e., failure to control for spillover effects and failure to control for regression to the mean; inappropriate application of statistical techniques; reliance on total crash numbers instead of target crashes) can make it more challenging to achieve consensus in the field about the effectiveness of photo enforcement. Nevertheless, dozens of studies have been conducted around the world on this topic. These studies have utilized different methodologies, different populations and different data sources. Some studies have also compared photo enforcement with other measures such as increasing the length of the yellow light phase. While there is clear consensus that such engineering measures are necessary to improve intersection safety, researchers also generally agree that these measures are not sufficient and that further gains can be made by using additional safety measures such as photo enforcement.

An examination of all the available evidence regarding photo enforcement as an additional safety measure has been conducted in several systematic reviews of the literature. These systematic reviews demonstrate a convergence of the evidence in favor of photo enforcement. This means that, despite the differences across studies, the findings are, in general, highly similar with few exceptions. There is converging evidence showing that photo enforcement leads to a reduction in speeding violations and red light running violations as well as reductions in right angle crashes and injury crashes beyond reductions that can be achieved with engineering measures such as longer yellow light phases. On the other hand, the results also show that increases in property damage only crashes and rear end crashes in the case of red light cameras can and do occur. Given that the consequences associated with property damage only crashes and rear end crashes are typically less severe than with other crash types, generally it is concluded that there is a net benefit, despite increases in some crash types.

It warrants mentioning that the money saved as a result of photo enforcement cameras fuels the maintenance and continued implementation of these programs, while the remaining money generally goes to the state or province's treasury and can be used to better serve the public.

In summary, while it is clear that there is a large body of literature demonstrating the positive impact of photo enforcement programs, results of a minority of studies do raise some questions about the effectiveness of this strategy. Of considerable importance, authors of these studies that question photo enforcement do not support a total abolition of photo enforcement but rather suggest that further research is needed to better understand the impact of photo enforcement at different types of intersections and under different conditions. For example, Garber et al. conclude in their 2007 report that their "results cannot be used to justify the widespread installation of cameras because they are not universally effective. These results also cannot be used to justify the abolition of cameras, as they have had a positive impact at some intersections and in some jurisdictions. The report recommends, therefore, that the decision to install a red light camera be made on an intersection-by intersection basis. In addition, it is recommended that a carefully controlled experiment be conducted to examine further the impact of red light programs on safety and to determine how an increase in rear-end crashes can be avoided at specific intersections (quoted from abstract)." Such recommendations are made by other researchers including Washington and Shin (2005: p. 123). In sum, it can be concluded that a consensus exists among the majority of researchers in the field that photo enforcement is an effective safety measure but some researchers do voice concerns about some undesirable side effects and state that more research is needed to further investigate optimal conditions for these programs.

# 3. PROCESS EVALUATION

## 3.1 Introduction

Jurisdictions across North America are increasingly implementing photo enforcement devices such as speed cameras and/or red light cameras to augment and enhance standard police enforcement techniques. This has occurred as part of an effort to reduce speeding and red light violations, and the serious consequences associated with these high-risk behaviours. The goals of photo enforcement are two-fold: 1) to reduce both speeding and red light running; and, 2) to ultimately reduce the number of crashes associated with these traffic violations and the fatal and serious injuries that result from them.

As mentioned previously, the Traffic Injury Research Foundation was contracted by the Winnipeg Police Service to undertake a rigorous evaluation of Winnipeg's Photo Enforcement Program. The methodology for this study includes a literature review, a public opinion poll, a process evaluation and an impact or outcome evaluation. This section of the report describes the findings of the process evaluation component of the study.

Whereas an impact evaluation determines whether the implementation of an application led to the desired effects (e.g., fewer drivers who speed and/or run red-lights; fewer collisions), a process evaluation investigates why these effects, or lack thereof, occur (e.g., problems with equipment; inconsistent ticketing; lack of public awareness; limited changes in behaviour). A process evaluation helps to explain why – or why not – particular effects were produced, and leads to the identification of elements that need to be modified or improved to produce the desired outcomes. It is used to determine what occurred and what was learned during the implementation of the program and what problems may have been encountered. The information that is acquired can ultimately be used to improve the program. It can also provide guidance to other jurisdictions seeking to implement a comparable program.

The overall objective of this process evaluation is to document the development and implementation of Winnipeg's Photo Enforcement Safety Program, and to explore the experiences and perspectives of participants that were involved in this process. The goal is to increase understanding of the program and provide insight into what strategies have worked well, where challenges or gaps (if any) occurred, and identify potential areas for improvement. More precisely, the goals of the process evaluation are to gain a more thorough understanding of:

- the knowledge, opinions, and experiences of program managers and staff regarding the program;
- the role of the different agencies involved in the program;
- any strengths or barriers associated with fulfilling roles and/or objectives; and,
- to identify recommendations regarding ways to improve the delivery of the program.

Information about the implementation of the program and how it has been/is being delivered was collected in 2010 through in-depth interviews with key people involved in the project. A wide variety of relevant documents pertaining to the program were also reviewed as part of the evaluation to provide additional detail about key program components, strategies and challenges. These documents included the Provincial Steering Committee report; the Highway Traffic Amendment and Summary Convictions Amendment Act; the Conditions of Authority that stipulate the terms and conditions under which the City's authority for the program is subject; the Image Capturing Enforcement Regulations which prescribe the use of intersection safety camera systems, vehicle-mounted photo radar systems, and trailer-mounted photo radar systems; Annual Reports generated by the City of Winnipeg; and the 2006 Photo Enforcement Program Review conducted by the Audit Department. Collectively, this information provides important context to interpret and better understand the results from the quantitative analyses pertaining to public opinion data, collision data, and roadside survey data for the outcome evaluation.

### 3.1.1 Program overview

The strong and consistent enforcement of traffic laws to prevent and reduce a wide range of traffic violations is essential to protect the public and increase road safety. Law enforcement activities have been repeatedly proven to create a general deterrent effect that discourages a majority of citizens from violating these laws and placing other citizens at risk. However, this task is not an easy one. Consistent enforcement of traffic laws requires significant police manpower and resources to sustain it. And, these resources are spread increasingly thin as police agencies are challenged to address emerging problems (e.g., airport security) and new and specialized demands for service (e.g., gangs, computer crimes). Hence, cost-effective strategies are needed to ensure agencies can maintain routine activities (e.g., traffic enforcement) and levels of service while responding to growing responsibilities.

This changing environment in combination with economic challenges have resulted in the increasing use of photo enforcement devices such as speed cameras and/or red light cameras in conjunction with traditional police traffic enforcement techniques. Collectively, efforts are needed to ensure that speeding and red light violations are controlled to protect the public and reduce the number of road fatalities and serious injuries as well as the social costs of crashes.

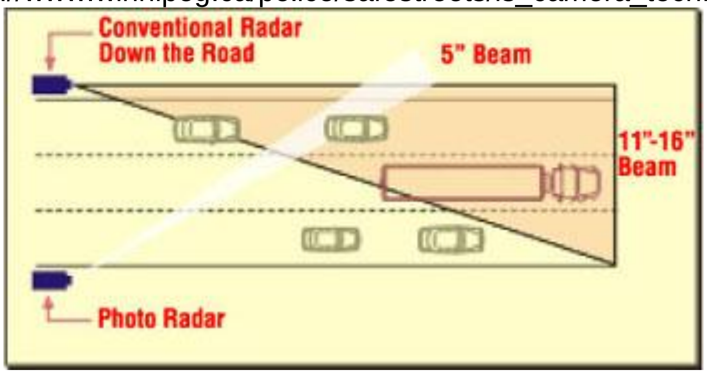
Photo enforcement cameras are designed to automatically photograph vehicles that pass through the intersection after the light has turned red and/or at speeds surpassing the indicated speed limit. Activation of photo enforcement cameras requires the use of triggering mechanisms. These mechanisms serve to detect traffic violations and to subsequently activate enforcement cameras.

Speeding is typically detected using radar technology, while detection of red light running requires the use of road tubes, loops, or sensors in order to detect vehicles as they pass through the intersection. The Winnipeg photo enforcement program utilizes technology manufactured by Gatsometer BV for both mobile photo radar, as well as Intersection Safety Camera systems.

The mobile photo radar units are used to detect speeding within construction zones, school zones and playground areas. These units are mounted in vehicles which are provided by ACS Public Sector Solutions and manned by special constables. The mobile photo radar system utilizes a radar control unit which detects vehicles passing by at speeds in excess of posted limits and then triggers the activation of the camera control unit. The radar control unit can capture vehicles driving at speeds between 20 km/h and 250 km/h. The system is independently powered by a rechargeable DC power source. The mobile photo radar system is functional in a wide range of weather conditions.

It should be noted that the photo radar beam coverage is different from conventional radar. As can be seen in Figure 3-1, the photo radar beam is more vehicle-specific than conventional radar eliminating the need for officer interpretation. If more than one vehicle is in the beam when a violation occurs, the photo radar unit does not trigger the camera to take a photo of the violation.

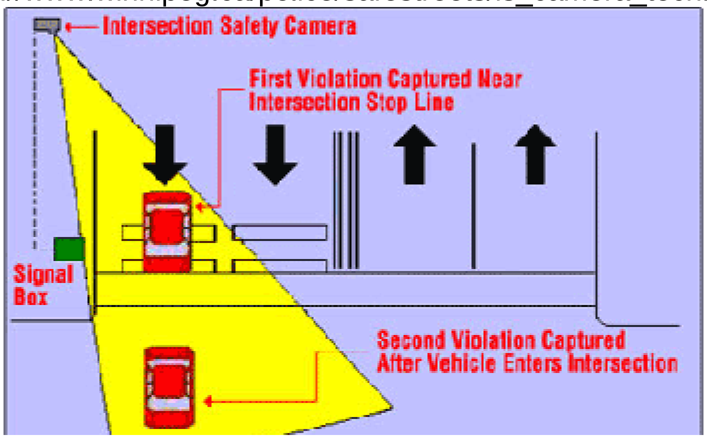
Figure 3-1: Difference in beam coverage between conventional radar and photo radar (http://www.winnipeg.ca/police/safestreets/is_camera_tech.stm)




With respect to both speeding and red light running occurring at intersections the Winnipeg photo enforcement program utilizes a system that was designed by Gatsometer BV. This technology can detect both speeding and red-light offences.

To detect red-light running, the automated photo enforcement system is activated once the traffic signal has turned red. At this point, any vehicle that passes over the magnetic sensors (which are placed strategically below the pavement along several points of the intersection) will trigger the camera to photograph the violating vehicle as it passes through the intersection. Thus, cameras are triggered when a vehicle is detected passing through the intersection after the traffic signal has turned red (see Figure 3-2).

Figure 3-2: Typical intersection safety camera set up
(http://www.winnipeg.ca/police/safestreets/is_camera_tech.stm)




To detect speeding at intersections, these same sensors detect the presence of vehicles and calculate their speed using time and distance. If the speed of the vehicle exceeds the predetermined speed threshold, the camera will be triggered to photograph the violating vehicle as it passes through the intersection.

Once a traffic violation occurs and a photo is taken, the film and data card are collected and processed and the film is sent out to be developed. The film is then reviewed by ACS and it is determined whether the event constitutes a potential citation. At this point the citation is either accepted or not accepted. If the citation is accepted, the citation number and licence plate number are sent to the Province where the registered owner name and vehicle information are retrieved and returned to ACS. If there is a vehicle match, the citation is accepted by ACS. Prior to issuance, a peace officer will then verify that the criteria of an offence are met and confirm that the vehicle information is correct. After these verifications have taken place, the citation is approved, and electronically signed, triggering the printing of an Image Capturing Enforcement Offence Notice by ACS. Offence notices are then mailed to the registered owner's address and considered personally served seven days after it was mailed.

Once received the registered owner has the option of either entering a plea of "Guilty", and paying the fine, or entering a plea of "Not Guilty". If a guilty plea is entered, the offender must pay the fine to the Province. Payment of the fine is considered an admittance of guilt and a conviction is entered against a person who voluntarily pays a fine. To plead not guilty, the owner named in the ticket must enter a "Not Guilty" plea. A dispute of the charge can be made before the court in person within 15 days after delivery of the notice, or a dispute may be mailed with a written explanation of the grounds for the dispute. If the driver of the vehicle at the time of the offence was not the owner, the owner can get a written statement from the driver indicating that the driver at the time of the offence was not the owner. Alternatively, the driver may attend court, and if the owner is not present at this time, the driver will need written authority from the owner to deal with the matter in lieu of the owner. The court then decides whether the fine will be unchanged, reduced, or eliminated. If the fine remains and the fined individual disagrees and does not pay the fine, the Province takes action to collect the outstanding fine.

Should the registered owner fail to respond within the specified dates a default conviction will be entered which results in the original fine being assessed as well as an additional monetary default conviction fee. If convicted by default, the ticket can still be contested by applying for a new hearing, or the fine can be paid. Fines are paid to the Province and the Province remits a portion of the fine revenue to the City of Winnipeg upon collection.

### 3.1.2 Agency roles and responsibilities

The program is primarily governed by the Highway Traffic Act and Summary Convictions Act. It is also governed by the Conditions of Authority and Image Capturing Enforcement Regulations. The Conditions of Authority is an agreement between the Province and the City and stipulates the terms and conditions under which the City's authority for the program is subject. The Image Capturing Enforcement Regulations prescribe the use of intersection safety camera systems, vehicle-mounted photo radar systems, and trailer-mounted photo radar systems.

A number of different agencies are involved in the delivery of Winnipeg's photo enforcement program. A brief description of each of the agencies involved in the photo enforcement program and a summary of their respective roles and responsibilities relative to the program are provided below.

The Winnipeg Police Service has oversight of the entire photo enforcement program. Specifically, the Winnipeg Police Service has four staff members (two police officers and two civilians) assigned full time to manage the program and the program is their overall responsibility. They ensure that the terms of the contract are fulfilled and that the criteria relating to the deployment of intersection and mobile units are met by the operators of the program.

ACS Public Sector Solutions (herein referred to as ACS) employs staff to operate the photo enforcement systems. ACS has recently been acquired by Xerox, so they are now “ACS, a Xerox company”. ACS does not manufacture the equipment. They provide, install and maintain the equipment and vehicles for both the intersection cameras and mobile radar. ACS captures the traffic violations on film, processes the violations, and generates and mails the offence notices. They prepare and mail the court packages at their processing centre. The packages include photos of the violation, a log sheet, vehicle registration information, the statement of a peace officer and a testing certificate for the equipment. It should be noted that these packages are only sent to the court in the event that a trial date is set. ACS has three field service technicians who are responsible for changing out the films and data cards and conducting tests at the sites. In addition to this, they produce program reports for the Winnipeg Police Service (and other specialized reports upon request) for the 48 enforcement intersections and ten mobile speed enforcement vehicles. Data that are provided from the equipment include the average speed of all vehicles passing through the intersections or designated areas as well as the number of speeding infractions.

Traffic Safe Solutions, Inc. is sub-contracted by ACS to provide staffing for the mobile photo radar units. At the beginning of the program, the Corps of Commissionaires was sub-contracted to perform these duties. However, the subcontractor subsequently was changed to Traffic Safety Solutions in July of 2009 based upon a decision by ACS.

Tri-Star Traffic & Distributing Inc. is contracted by ACS to work solely on the intersection safety camera locations. This includes all the work required to set up a new location (e.g., sensors in the road, installing the poles for the cameras, etc.). They are also responsible for any substantial maintenance or repairs on the intersection safety camera locations. In addition, they gather the camera and speed unit data for the outcome evaluation of the program. This information has been provided to TIRF for the purposes of this evaluation. It should be noted however, that these data were collected separately for the outcome evaluation using a different methodology than that of the safety program and only for a specified period of time.

Manitoba Courts is responsible for any adjudication of the offence notices and the collection of fines. These fines are then paid to the City on a monthly basis. Specifically, the Summary Convictions Court in Winnipeg processes all tickets related to photo enforcement that are issued by the Winnipeg Police Service. Manitoba Justice was involved in the drafting of the photo enforcement legislation and responding to any legal challenges associated with the law.

In terms of the technology used in Winnipeg's Photo Enforcement Safety Program, Gatsometer BV is the manufacturer of both the mobile photo radar equipment and Intersection Safety Camera Systems.

## 3.2 Objectives and Research Questions

As part of the process evaluation, TIRF staff conducted a small number of qualitative interviews by conference call with key staff who are involved in the Photo Enforcement Safety Program and who could provide important insights into the development and functioning of this program. An appropriate protocol for interviews was developed by TIRF in advance of the interviews to facilitate the efficient collection of data. In addition, all relevant documentation was obtained and reviewed to identify topics for discussion and guide the exploration of key aspects of the program with participants. These data were also analyzed and used to place the process evaluation results in a broader context.

### 3.2.1 Research questions

The research questions listed below represent examples of questions that are typically posed as part of a process evaluation. Answers to these questions provide the necessary knowledge to understand why, or why not, a program is effective, its strengths, any gaps that exist, and opportunities for improvement. This serves to identify where and why challenges occurred and ways that the program can be strengthened. The answers to these questions also provide information that could be used to inform the implementation of other, similar programs. Below is a list of questions that are provided as some examples of the types of questions that were considered as part of the process evaluation.

- Management of the program
  - What agency has responsibility for oversight of the program?
  - What roles did each agency have in the delivery of the program?
  - How was the technology selected and how reliable was it?
  - Were any problems encountered in terms of the maintenance and testing of the equipment?
  - Were there any equipment problems due to extreme weather conditions?
  - Were there any problems that were encountered with regards to the delivery of the program?
  - Was the delivery of the program transparent?
  - Was the public informed about and aware of the program? How was this achieved? Was the public able to adequately understand the law and the program?
- Terms of contracts with service providers
  - How was the contract with service providers developed and how were the service providers selected?
  - Were the terms or conditions of the contract changed during the course of the program? If so, why?
- Selection of sites
  - What agencies were involved in the selection of sites?
  - Other than the criteria set out in the provincial legislation, what factors or criteria were taken into consideration when selecting the sites for the intersection safety cameras?
  - Was there any difference in the selection of sites for the mobile photo radar units?
- Staffing issues
  - Were there any problems associated with hiring an adequate number of people to staff the program?
  - Was there sufficient staff to operate the program at full capacity?
  - How were staff trained and by who?
  - Were staff roles and responsibilities clearly articulated?
  - What does the staff consider to be the strengths/weakness of the program?
  - How satisfied was the staff with the delivery of the program?
- Revenues and expenses
  - How was projected revenue for the program calculated?

  - » Was the budget/revenue projection process effective?
  - » How did this affect the delivery of the program?
  - » What changes, if any, were made to the program to account for expected vs. actual revenue?

> Information sharing

  - » Did agencies feel they had adequate access to relevant information to inform decision-making?
  - » Were there any limitations that were encountered in terms of obtaining sufficient information about the effectiveness of the program?
  - » If so, how did this affect the ability to guide the implementation of the program?

> Political support

  - » How supportive was City Council with regards to the implementation of the photo enforcement program? How accepting were they of the program?
  - » How supportive was the Province with regard to the implementation of the program? How accepting were they of the program?

> Public awareness

  - » What efforts were made and what strategies were utilized to inform the public about the program?
  - » Were the goals of the program clearly communicated to the public?

> Public support

  - » How did the public react to the implementation of the program?
  - » Was the public supportive or not supportive of the program and why?
  - » What effect, if any, did the public's perceived fairness of the program have on the delivery of the program?
  - » Were any modifications made to the program to address any public concerns?
  - » What efforts were undertaken to increase public support for the program?

> Legal challenges

  - » Were offence notices issued within a sufficient time frame (14 days before the violation is void) in accordance with the law?
  - » Were there any problems encountered in terms of issuing offence notices or collecting fines?
  - » Were there any problems associated with ticketing or the issuance of offence notices, and, if so, how were these addressed?

> Compliance with external authorities

  - » Was the program delivered in accordance with the Highway Traffic Act?

  - Was it delivered in accordance with the Conditions of Authority?
  - Were any problems encountered?
- Efficiency of the program
  - What performance measures were considered to evaluate the program? Were these considered adequate?
  - Were there any concerns about the workload associated with the program?
  - What, if any, effect did the program have on the amount of court time spent on traffic offences?
  - Were there delays in the processing of offences?
  - Were any changes in the court process introduced to account for the program?

## 3.3 Methods

The process evaluation began with a preparatory phase to organize a series of qualitative interviews with key people involved in the project, both past and present, to obtain information about the implementation of Winnipeg's Photo Enforcement Safety Program and its ongoing delivery. This phase involved the collection and review of qualitative background information about the program, the identification of relevant participants, and the organization of and preparation to conduct the interviews. The interviews were structured to identify priority issues, strengths and challenges related to the implementation and delivery of the program in accordance with each agency, and to gather the experiences and perspectives of the participants in relation to key issues.

Once the interviews had been conducted, and the subsequent follow up with participants to clarify details was completed, this information was synthesized and interpreted with respect to the way that the program was planned and understanding gathered from the literature. It was further considered in light of documentation that had been collected and the results of data analyses.

### 3.3.1 Preparatory phase

During the preparatory phase of the evaluation, a timeline of key activities and milestones was developed. The timeline included relevant steps that occurred from the moment the implementation of a Photo Enforcement Safety Program was first envisaged until the actual implementation of the program was completed and the program was operational. Key steps pertaining to the implementation of the program, and agencies that were involved were also identified. This resulted in the development of a detailed timeline that highlights the critical actions that occurred in Winnipeg (see Appendix A). This task was completed based upon documentation (e.g., legal documents, policy documents, and other reports and relevant sources of information) that was gathered. The timeline was further augmented based upon discussion with key participants throughout the course of the project.

Stakeholders and agencies that played a prominent role during the preparation, implementation and delivery of Winnipeg's Photo Enforcement Safety Program are included and identified in this timeline. This information was obtained through relevant documentation, discussions with program and project staff, and interviews with key staff representing the Winnipeg Police Service, Manitoba Department of Justice, and ACS.

Once the timeline was developed and key stakeholders had been identified, all the relevant documents from each agency (e.g., the Provincial Steering Committee report, the Highway Traffic Amendment and Summary Convictions Amendment Act, Photo Enforcement Annual Reports, the 2006 Photo Enforcement Program Review conducted by the Audit Department, etc.) were critically reviewed to identify each of the steps that were taken by agencies to prepare for the full implementation, to gain insight into the context in which the program was implemented and to identify any issues that were raised in the documentation.

The information obtained during this preparatory phase was then synthesized and used to guide the discussions during the qualitative interviews.

### 3.3.2 Qualitative interviews

In order to gain a clear understanding of the implementation of Winnipeg's Photo Enforcement Safety Program and potential challenges and concerns across agencies, a series of qualitative interviews with key staff of agencies who were involved in the implementation and/or delivery of Winnipeg's Photo Enforcement Safety Program were scheduled. Key agencies represented included:

- Winnipeg Police Service;
- Manitoba Department of Justice, Courts Division;
- ACS, also representing its sub-contractors.

TIRF identified key staff to participate in these interviews based on discussions with program staff and a review of available documentation. During these interviews the implementation of the program was explored in relation to its strengths and challenges. Obstacles that were encountered were discussed along with opportunities for improvement.

The outcomes of each of these interviews have been synthesized by TIRF in conjunction with the information gathered during the preparatory phase of this process evaluation. These results are described according to a range of key topics in the following section.

## 3.4 Results

As mentioned previously, the purpose of this process evaluation was to gather more information in terms of the historical background of the program and to gain insights into the development and delivery of the various aspects of it. This information can help place the results of the evaluation in context and provide a complete understanding of program. This section contains the results stemming from the review of program documentation in conjunction with the outcomes of the interviews with key program staff.

This section is structured according to the following topics:

- The context of the implementation of the program;
- Internal planning and preparation to implement the program;
- Development of service provider contracts and the selection process;
- The selection of site locations;
- Staffing;
- Management of the program;
- Sharing of information;
- Legal challenges;
- Public awareness initiatives;
- Public support;
- Revenues and expenses;
- Compliance with external authorities.

### 3.4.1 Context of implementation

The environmental context and situation that exists in a jurisdiction prior to and during the implementation of any program or policy is of importance to a process evaluation. In some instances, challenges associated with the implementation can occur due to external decision-making by outside agencies, a changing political environment or a changing economy. Such examples can clearly illustrate how unrelated factors can either enhance implementation, or, conversely, compound or amplify implementation issues and can create unintended negative consequences that may have been otherwise less significant or even non-existent. As such, as part of any process evaluation it is important to distinguish between factors directly related to implementation, and pre-existing and external factors in order to fully appreciate the results of the evaluation. In Winnipeg, there were important situational circumstances that existed prior to or in conjunction with the implementation of the Winnipeg Photo Enforcement Program that are directly relevant for the purposes of this evaluation.

First, prior to the implementation of the current photo enforcement program, the increase of red-light running and speeding resulting in the loss of life as well as the increased costs of healthcare and collisions had been identified as major concerns to the citizens of Winnipeg (source: Steering Committee report). It is difficult to sustain traditional enforcement tactics from a resource perspective. In addition, such tactics can pose an elevated risk of injury or fatality to law enforcement officers and other road users depending on the environment in which it is applied. More importantly, these strategies are less efficient and cannot cover many areas at once without adequate manpower. Conversely, automated enforcement technologies such as intersection cameras and photo radar have been used in other jurisdictions and have been shown to reduce collisions. Combined, these factors created a strong motivation for officials to consider and to explore photo enforcement as a strategy to address public concerns about speeding and red light running.

As a result of this situation, the City of Winnipeg first requested amendments to provincial legislation in November of 1994 to permit the use of photo radar by the Winnipeg Police Service. However, political support for the program across the Province at this time was low. In response to this request, the Winnipeg Police Service was instructed to provide further evidence that photo radar would reduce motor-vehicle collisions.

Second, in 1997, a series of public forums was held during which the citizens in attendance identified traffic safety as the primary safety concern. Following these forums, the Winnipeg Police Service again initiated discussions with the Province with regard to the use of photo enforcement. In response, legislation was subsequently introduced which enabled the use of red light cameras and rail crossing cameras, but it did not enable the use of photo radar. The City endeavoured to implement a program at this time and did issue a request for proposals (RFP), but no service providers responded by submitting a bid so it was not possible to pursue the implementation.

Third, support for the program significantly increased following the election of a new mayor and the appointment of a new police chief. Again, City Council formally requested the enactment of provincial legislation to enable the use of photo radar in May, 2000. Subsequent to this request, the Minister of Transportation and Government Services directed the creation of a Working Group to review the issue and prepare a report describing recommendations pertaining to the feasibility, development, implementation and evaluation of a photo enforcement program in Manitoba. The report was completed in May 2001 and it was recommended that Provincial approval be given to enable the implementation of photo enforcement in the province.

On May 8, 2002, the Standing committee on Law Amendments met in the Legislative Assembly of Manitoba to discuss Bill 3 – The Highway Traffic Amendment and Summary Convictions Amendment Act. A presentation was made to the Assembly requesting Bill 3 be considered on behalf of the Winnipeg Police Service. On May 23, 2002 the Province of Manitoba amended the Highway Traffic Act with the Highway Traffic Amendment and Summary Convictions Amendment Act. This amendment allowed for the use of image capturing enforcement systems by municipalities to enforce red-light offences and speeding offences. The City of Winnipeg entered into an agreement with the Province, known as the Conditions of Authority, on December 11, 2002. This agreement provided the City with the proper authority to implement a photo enforcement program and enabled the program to become operational. On December 16, 2002, the Image Capturing Enforcement Regulation came into force authorizing the City to begin utilizing photo enforcement.

In summary, leading up to the implementation of the current photo enforcement program, there were high levels of public concern regarding speeding and red light running. There were also two earlier initiatives to implement the program, creating opportunities to raise political awareness and develop political support at different levels of government for the program. This created a very positive environment with public demand to improve traffic safety and strong political support to ultimately implement the current photo enforcement program.

**3.4.2 Internal planning and preparation**

The implementation of a photo enforcement program requires considerable planning and preparation across agencies in order to effectively deliver services. In Winnipeg, a Steering Committee comprised of representatives from key agencies that would be involved in the program was formed. A Project Committee was also formed to collect data and information about photo enforcement and its use in other jurisdictions.

There were 10 members of the Steering Committee which included senior representatives from the Departments of Transportation and Government Services, Justice and Intergovernmental Affairs, the City of Winnipeg, The Winnipeg Police Service, the City of Brandon, the Association of Manitoba Municipalities and Manitoba Public Insurance. The Steering Committee was chaired by the then Deputy Minister of Transportation, Andy Horosko.

Membership for the Project Committee was comprised of 11 persons representing the provincial Departments of Transportation, Intergovernmental Affairs and Justice, along with the Winnipeg Police Service, Brandon Police Service, the Royal Canadian Mounted Police (RCMP) and Manitoba Public Insurance. The Project Committee was chaired by Senior Legislative Consultant, Transportation, Dianne deKock-Taylor.

The Project Committee researched and reviewed photo enforcement programs in other jurisdictions and also visited programs in another jurisdiction (Arizona) to gather additional information. It subsequently prepared a proposal regarding the feasibility, development, implementation, and evaluation of a photo radar enforcement program in Manitoba. The report consisted of a series of discussion papers and interim reports regarding photo radar practices and results in other jurisdictions for the Steering Committee's consideration. The contents of this report ultimately guided the development and implementation of the photo enforcement program in Winnipeg.

It should be noted that the program implemented in Winnipeg was unique and differed from those in other North American jurisdictions for three main reasons. First, the Manitoba legislation specifically limits the utilization of photo enforcement to particular locations whereas in other jurisdictions it is generally not limited. Second, the City of Winnipeg was the first program in North America to use the "speed on green" technology which records the speed of vehicles going through intersections with green and amber lights. And, third, as of 2007, the City utilized a hybrid contract with the service provider, involving a combination of a single fixed fee for service in combination with a contingency fee based on the number of tickets issued to better manage the costs associated with the program and reduce the City's level of risk. These three factors and their relevance to the implementation of the program are discussed in more detail later on in the report.

### 3.4.3 Terms of contracts with service providers

Photo enforcement is a major initiative requiring substantial initial and ongoing investment both in monetary and staffing terms. The majority of jurisdictions studied by the Working Group chose to outsource the technical and processing components of their program and this was deemed the most practical method to implement photo enforcement in Winnipeg. This practice is common in relation to many enforcement, corrections, and other public safety technologies (e.g., alcohol ignition interlocks, home electronic alcohol monitoring, GPS monitoring for offenders) because intensive training, specialized knowledge and technical expertise is required to manage the equipment, thus greatly increasing costs associated with training staff and maintaining/upgrading the equipment. It was therefore recommended by the Steering Committee that the Winnipeg Photo Enforcement Program be outsourced to private service providers.

The Winnipeg Police Service began a six-month pilot project of photo enforcement technology on October 19, 2001 involving only one intersection where an intersection safety camera would be installed and one location for mobile radar. Given the small size and limited cost of the pilot program, the service provider was sole sourced – i.e., the contract did not go to public tender. It is common for one service provider to be awarded a contract for these types of pilot programs. This occurs because it is too difficult and costly to train staff on a variety of equipment produced by different service providers. The downside of this, however, is that it is both difficult and costly to change service providers once a program is established because selecting a different service provider or product means costly re-training of staff, purchasing of new equipment and/or changes to program practices.

However, in preparation of the full implementation of the photo enforcement program, a Request for Proposal (RFP) was issued to all potential service providers for the program on March 29, 2002 in anticipation of the legislation to permit photo enforcement. The purpose of the RFP was to gather bids from different service providers and then select the contractor who would be responsible for the supply, installation and operation of the Winnipeg Photo Enforcement Program. As is standard practice, the project went to RFP because of the high dollar value of the contract.

The RFP was drafted by Materials Management, the department that is familiar with and responsible for City contracts, and that possesses extensive knowledge of the process of contracting on behalf of the City. Input was provided by the Winnipeg Police Service who had content knowledge and expertise about photo enforcement programs. In response to the RFP, three companies submitted proposals. The proposal of one company was not considered because it failed to meet the requirements of the RFP.

However, the RFP process was criticized. The RFP was issued before the Province proclaimed the enabling legislation which may have limited the number of responses to the RFP due to the level of political uncertainty and the complexity of responding to an RFP of considerable length as stated in the 2006 audit. The 2006 audit also stated that the RFP did not contain sufficient information of the cost component of bid submissions on which to base a realistic price estimate. This could be due to the fact that the pilot project was not yet completed when the RFP was issued. Thus, the results had not been fully evaluated which limited the amount of information available to accurately predict or estimate the number of offences. This may also partly be explained by the fact that this program was unique, hence costing it was somewhat different from other programs and there was no comparable example to follow.

The Winnipeg Police Service and the City of Winnipeg reviewed the two remaining proposals. The City of Winnipeg was represented by staff from Materials Management who oversees RFPs and purchasing, and the City's Chief Financial Officer. Materials

Management was also responsible for developing a point assessment schematic to evaluate the proposals. Only one company, ACS, was determined to have met the minimum proposal requirements. The other company appealed the decision and this resulted in a meeting between company representatives and the Chief Administrative Officer of the City, however the decision was upheld.

The 2006 audit also criticized these decisions stating that the RFP evaluation team was lacking in the financial or engineering expertise necessary to properly review the proposals, taking only five days to evaluate both proposals and failing to document the decision-making criteria. The documentation of decision-making criteria is important for accountability. Lack of proper documentation could make it difficult for the Winnipeg Police Service to properly defend the service provider selection process under public scrutiny. Documentation is also important for ensuring that the services to be provided were appropriate given the circumstances. The bid opportunity template used by Materials Management describes the method used by key personnel in the selection of contract proponents. In this document it is stated that all proposal submissions are treated as confidential. It is noted here that once a contract has been awarded, information related to the evaluation of a submission is provided to a proponent upon written request to the Project Manager. Thus, if this information were documented, it is possible that this information was not made available to the audit team due to the confidentiality stipulation. In addition, this RFP template clearly lays out the evaluation criteria that are applied in the selection process. For example, a bid may be rejected if the submission is incomplete, or contains any deletions or other irregularities. If any of the conditions of the evaluation were not met, the submission would be rejected. Even if all proposals demonstrate that the proponent is responsible and qualified, the City has no obligation to award a contract to a proponent.

On May 22, 2002, ACS was awarded the contract to provide services for Winnipeg's Photo Enforcement Program and on May 31, 2002, the Province entered into an information access agreement with the City and ACS. This agreement recognizes ACS as the photo enforcement service provider and grants it access to registered vehicle owner's information from the Manitoba Division of Driver and Vehicle Licensing.

Of interest, there are typically three different types of contracts that are used to secure photo enforcement services: 1) flat fee contracts which are a single fixed fee for a service; 2) contingency contracts which are contingent on the number of tickets generated by the program; and, 3) hybrid contracts which are a mix of flat fee and contingency contracts. The main difference between the three types of contract is the level of risk taken by the entity contracting for services.

ACS was awarded a five year flat fee contract by the City of Winnipeg in 2003. The flat fee contract option was selected because City officials believed that the use of a contingency contract based on the number of tickets generated would send the wrong message to the public and potentially contribute to the misperception that the purpose of the program was to generate revenue as opposed to improve traffic safety. The contract with ACS was extended for five more years in 2007. Generally speaking, contracts frequently involve an opportunity for extension and the number of times it can be extended is limited, in this case up to three times. The Chief Financial Officer for the City is responsible for the re-negotiation of City contracts. The new photo enforcement services contract was modified in 2007 and was based on a combination of flat-fee and per-ticket basis. It also included an increase in funds from the service provider to support public education initiatives and for evaluation of the program. This change was designed to better protect the City from risk and to make better use of program revenue.

On June 17, 2002, a tender was issued by ACS to select a subcontractor to supply mobile photo radar operators. The Canadian Corps of Commissionaires was awarded the contract on August 30, 2002. This contract was later reviewed and awarded to Traffic Safe Solutions Inc. in July of 2009, a decision taken by the service provider, ACS.

#### 3.4.4 Selection of sites

Prior to the implementation of the program, the Working Group recommended that photo radar sites meet certain high-risk criteria. Examples include locations with a high severity collision history, or areas where it is unsafe for traditional speed enforcement such as high-speed, multi-lane roadways. It was also recommended that photo radar not be positioned within a prescribed minimum distance following a speed zone change, an on/off ramp for a multi-lane limited access highway, or from the bottom of a hill.

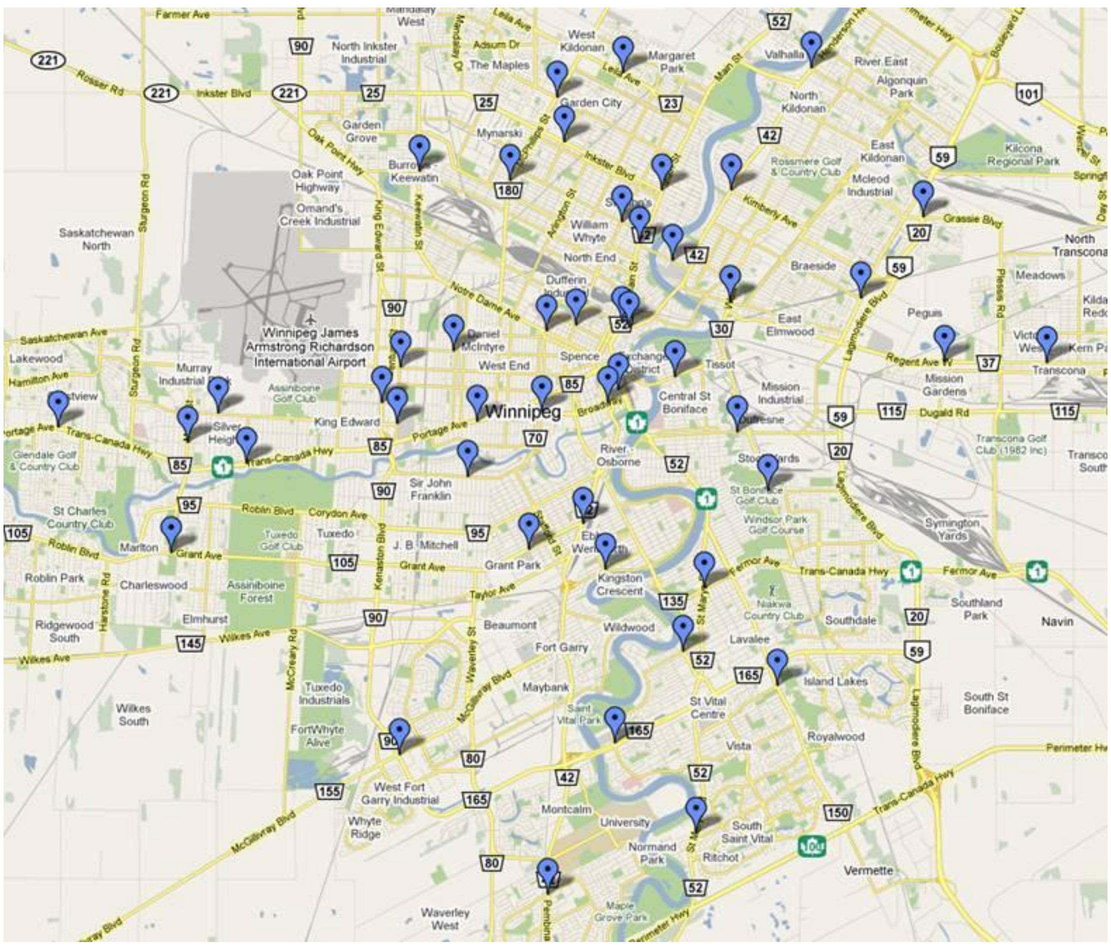
The selection of sites was primarily governed by the criteria set out in the Provincial legislation. These criteria varied according to the type of photo enforcement units being used. Mobile photo radar units were permitted to be deployed in school zones, playgrounds and construction zones. The limitations set out in the legislation had largely to do with political concerns and sensitivity to the potential perception that the motive of the photo enforcement program was to gather revenue. It was believed that, by limiting the use of cameras to specific locations, the misperception that photo enforcement was a revenue grab could be mitigated. It should be noted that that most other jurisdictions do not restrict the use of photo enforcement to certain types of locations, and this restriction did add complexity to the use of the program and site selection.

The criteria for intersection camera deployment included collision data, speed data, public input, the technical ability to install at certain locations, and distribution throughout the city 24 hours a day, seven days a week.

It was the role of the Winnipeg Police Service and the City of Winnipeg to select and approve the sites where the intersection cameras and mobile radar were deployed. This internal selection was largely guided by the criteria set out in the legislation. Public Works also had significant involvement in the selection of sites because infrastructure and construction were key factors in determining the feasibility of installing cameras at selected locations. Each camera location required a power source for the equipment and the cameras had to be placed at a particular location in relation to the traffic signals for logistical reasons. For example, if a man-hole was located where the camera pole would need to be installed or if a bus stop was in the way of the camera, this would preclude the location from selection. Due to the specific placement of the equipment, the location of street furniture such as bus stops is an important factor in determining where photo enforcement can be deployed. Collision data and public input also were important considerations in the selection of site locations (e.g., calls from the public reporting concern about a particular intersection).

It should be noted that not all photo enforcement locations are operational at all times, as the program had intended. To illustrate, in 2008, there were 33 cameras rotated through 48 intersection safety camera locations. Figure 3-3 below displays the locations of the 48 intersection safety camera locations in the City of Winnipeg. The reason for rotating cameras on a regular basis through different locations is to enhance the level of general deterrence and minimize the migration of traffic to other non-enforced areas or displacement, which is a concern of a variety of enforcement programs. One of the major factors taken into consideration in the rotation of the cameras is equal representation throughout the districts. The Winnipeg Police Service identifies six distinct districts for the tracking of activities and deployment of resources. Further consideration is also made with regards to locations which exhibit a continued pattern of unsafe driving behavior as reflected in the number of violations recorded. In other words, high-crash locations are given a greater priority.

**Figure 3-3**: Map of Winnipeg and photo enforcement intersections




An important challenge that has been noted with regard to the site selection process is that the legislation closely restricts the types of locations in which photo enforcement can be deployed, which was not the case in other jurisdictions that utilized photo enforcement programs. It is reported that this decision was based in part on political considerations. Prior to the implementation of photo enforcement in Manitoba, both British Columbia and Ontario governments had experienced a lack of public support for these programs. It was believed that, by limiting the use of cameras to specific locations, the misperception that photo enforcement was a tax grab could be mitigated. However, an unintended negative consequence of this decision was that it made it more difficult for the Winnipeg Police Service to deploy units in accordance with the strict requirements of the legislation in a dynamic road environment.

According to the 2006 audit of the program, how these criteria were applied, however, was not clear. There was limited documentation on file to support why certain locations were selected and others were not. The audit stated that staff could clearly explain how locations were chosen, however these decisions were not documented. Lack of proper documentation may impede the ability to properly evaluate the outcomes of the program and could make it difficult for the Winnipeg Police Service to properly defend the selection process under public scrutiny. In addition, without documentation, criteria could potentially be applied inconsistently which could result in inappropriate sites being selected. Documentation is also important for the use of other jurisdictions who may want to replicate such a program. It is noted that site selection criteria were subject to the limitations of the infrastructure in place at potential sites. This significantly contributed to the complexity of the site selection process and may explain the lack of documentation as intersection feasibility and the complex considerations involved in this determination is the ultimate hurdle with regards to site selection.

**3.4.5 Staffing issues.**

Prior to implementation it was decided that all members of the photo enforcement unit, including both Winnipeg Police Service staff assigned to the photo enforcement unit and the service provider’s employees, would be housed in the facility that was established and maintained by the service provider. It was expected that two members of the Police Service would be assigned to the unit – one constable with extensive experience with radar to assume the training position and one sergeant with overall responsibility for the unit and to coordinate the ongoing public education program. At this time, there are still two Winnipeg Police Service members who serve as the administrators of the program.

It was anticipated that the introduction of photo enforcement would significantly increase the volume of tickets processed and that this would have implications for the workload of Justice staff, in particular the courts. In other words, the program was expected to affect court staffing, specifically administrative/clerical staff, prosecutors, the judiciary, and the collections branch staff (responsible for collecting outstanding fines). The Courts division estimated that eight additional staff would be required. For example cashiers would be required to process "mail-in" payments, teletag (phone service), and "in-person" payments and two additional clerical staff to manage the additional paperwork. Additional justices of the peace would also be required to hear pleas of "Guilty with an explanation" and "Not guilty". The Courts division did in fact hire eight additional staff in varying capacities at the onset of the program: one justice of the peace, one sheriff officer, two systems staff and four support staff.

While at the outset of the program, more people chose to challenge the photo enforcement tickets, the number of people who currently challenge tickets in court has declined. According to Justice staff, it appears that the program has contributed to increased ticket volumes and processing times, mainly in terms of the processing of cashier payments and the volume of mail that must be managed. Much of the workload is placed on the front counter as this is where people can appear before a justice of the peace to enter a plea.

The staff that operates the mobile photo radar equipment are special constables instead of police officers and this was a strategic decision. If the operators were fully trained police officers, the program would be much more costly to sustain. Fully trained law enforcement officers receive a broad range of training in regular law enforcement duties as well as considerable specialized training (e.g., use of force, firearms training, Criminal Code offences, emergency situations) to deal with many different levels of risk. Such extensive training to manage such diverse situations is not necessary to operate photo enforcement equipment. To better manage program costs, the equipment operators instead were granted special constable status.

The Corps of Commissionaires was selected both in Calgary and Edmonton as photo equipment operators. As such, this is why they were initially chosen to staff Winnipeg's program. They were also initially chosen for the program because they have a background which is similar to that of the police with an emphasis on duty. For example, the Commissionaires have been successful in by-law enforcement for years. In July of 2009, ACS elected to change subcontractors from the Corps of Commissionaires to Traffic Safe Solutions Inc.

The change from the Corps of Commissionaires to Traffic Safe Solutions Inc. did pose a potential problem for the Winnipeg Police Service in that this new provider would be responsible for making the application for special constable status for photo equipment operators. Mainly this was a problem because the Police Service received just 24 hours notice of the change. The potential problems this created for the Police Service (with regard to applications for special constable status) was raised with ACS and this issue will subsequently be addressed within any future contract process.

With regard to staffing by the service provider, ACS has 19 employees and 30 staff employed by subcontractors, ranging from those who process the film to those that clean the facilities. Overall, there is little turnover among ACS staff. It was noted that, with regards to staffing, Winnipeg is the most stable photo enforcement program in Canada and one of the most stable when compared to those in the U.S. There is limited turnover among administrative and management staff, resulting in employees with considerable experience. In terms of training, most staff training occurs in-house by ACS. The only exceptions are for some specialized training that is completed at the U.S. office of ACS or when there is specific equipment training in which case, staff is sent to the manufacturer. In addition, many staff are cross-trained to perform the duties of other positions to reduce the potential for interruptions in service in the event of unforeseen challenges.

However, there was higher staff turnover among the photo radar operators (e.g., the staff who man the mobile radar vehicles). Many of the Corps of Commissionaires employees recruited were either retired military or public sector employees. This posed a staffing issue due to the constant turnover and continued need for training of new photo radar operators.

In summary, the photo enforcement program is operated with a minimal number of Winnipeg Police Service staff, and it is reported that in general, the Winnipeg Police

Service supports the program. While the photo enforcement program has effected staffing at Justice, the staff is able to work effectively with the program. Finally, there is also a high level of satisfaction among service provider staff at ACS with the program.

### 3.4.6 Management of the program

**Authority**. While the Winnipeg Police Service is responsible for the management of the entire photo enforcement program in Winnipeg, there is a clear division of duties. Corporate officials representing the City are responsible for administrative and contracting tasks associated with the project, whereas the Winnipeg Police Service is responsible for operational tasks. There are two officers from the Winnipeg Police Service devoted to the administration of the program.

One management issue that has been noted is that Winnipeg's photo enforcement program is managed and delivered by the Winnipeg Police Service (and the City); however the program is enabled by provincial legislation. In other words, provincial legislation sets out the conditions under which the program is regulated, and the City of Winnipeg and the Winnipeg Police Service must manage the program according to these conditions. On one level, this presents its own challenges as the operational practices generally employed by municipalities and law enforcement agencies to manage such programs may inherently conflict with legislation implemented by the Province. One example of this relates to the issue of signage in construction zones discussed in the legal challenges section of this report.

**Agency partnerships**. Since there are multiple agencies involved in this initiative, relationships between program partners are important to its success. The Winnipeg Police Service reports that overall, a positive working relationshsip has been established with ACS. There has been good communication and ACS has been responsive to requests. The only issue that posed a challenge was the decision of ACS in July 2009 to change the subcontractor that managed the mobile radar units. As mentioned previously, Winnipeg Police Service received 24 hours notice of the change of subcontractor from the Corps of Commissionaires to Traffic Safe Solutions Inc. As highlighted, this was a potential issue due to the fact that the photo radar operators for the program are required to be appointed special constables. Despite this short notice, the new subcontractor was able to secure the appointments of all operators with no interruption of service. As stated previously, this concern was brought to the attention of ACS by the Winnipeg Police Service and will be addressed as part of the contract process.

Similarly, ACS also reports that there is a positive client relationship with the Winnipeg Police Service and they are satisfied with the terms and conditions of their contract. They report that the situation of having Winnipeg Police Service administrative/clerical staff in the ACS building has greatly facilitated communication between the two agencies and strengthened their working relationship. Both agencies agree that this situation also provides for good quality control of the program. ACS also reports that they utilized a variety of checks and balances that are relied upon as an internal quality assurance program. For example, many staff are cross-trained to perform the duties of other staff in the event this is required.

**Equipment**. Agencies agree that the equipment purchased for the program is of high quality and is produced by well established service providers. The testing of the equipment is regulated by the Province and occurs regularly in accordance with these requirements. The technology used is very reliable and generally, there are no weather related issues except for a limited number of snow covered licence plates. Thus, the equipment is fairly robust in all weather conditions. With regards to the equipment, one or two system upgrades are performed each year by ACS. Very few extra or emergency upgrades have been required. One example of system upgrades relates to the ability to produce offence notices in French.

The only exception with regard to the equipment is that manufacturers are no longer producing the analogue technology which utilizes wet film. The Winnipeg Photo Enforcement Program currently uses analogue (wet film) technology for both mobile and intersection camera systems. This is a growing concern, as it has been in other jurisdictions, because few manufacturers are continuing to produce wet film. Digital cameras have become available and more jurisdictions with a photo enforcement program have made this switch. For this reason, managers of the Winnipeg program are considering making the change from wet film to digital equipment. This transition will have significant costs and would likely occur over a period of three to four years in order to manage these costs. Winnipeg Police Service has consulted with the service provider on this issue, and ACS is working with the Police Service so it can be addressed in a cost-efficient manner and to avoid interruptions in service.

One obstacle to this transition is that a legislative amendment would be required to permit the use of digital equipment. The Winnipeg Police Service is reluctant to move forward with the transition to new equipment prior to a change in legislation being granted. If the legislative amendment is not approved and wet film is no longer available, then the program would no longer be able to operate.

**Courts**. From a Court perspective, the program is well-managed and it has posed no major problems for the courts. With regards to generating offence notices, mobile enforcement is more efficient for generating speeding offence notices compared to intersection cameras in terms of the rate of violations that result in offence notices. This could be due to the fact that intersection cameras are located at high traffic locations where speeding is more difficult. There have not been any delays in processing the offences. Offence notices must be issued within 14 days of the offence; generally notices are issued within an average of seven days.

In terms of workload, it is noted that the cashier counter is reported to be busier with the increased volume of tickets that are generated by the program. On average, staff estimate that no more than 10% of cases go to court and cases may last 20 minutes on average, depending on the circumstances of the case. Staff believes that the percentage of cases involving a challenge of the ticket has been declining as generally, most people pay the fine.

According to the 2006 audit, only about 2% of all offence notices are contested in court. Overall, cases from the program are not overly lengthy, on average taking about 20 minutes. Photo enforcement has contributed to increased ticket volumes and processing times. However, trial wait time is now between eight and nine months.

### 3.4.7 Information sharing

The sharing of information is also an important aspect to any program involving multiple agencies. Since the Winnipeg Police Service is responsible for managing the photo enforcement program, data and information about the program are required to fulfill this responsibility. The majority of the information regarding the program received by the Winnipeg Police Service is provided by ACS, the service provider responsible for the delivery of the program. For example, ACS provides statistical and financial reports requested by the Winnipeg Police for the purpose of completing annual reports which are produced for the Province. Information contained in the statistical reports includes the number of offences and clearance status for both intersection safety cameras and mobile radar vehicles and 85$^{th}$ percentile speeds on particular roadways. There have been no reported issues regarding information sharing between the Winnipeg Police Service and ACS, and the Police Service notes that it receives adequate information to effectively manage the program. ACS is helpful in responding to data requests from the Service.

Generally, Manitoba Justice provides limited information to the Winnipeg Police Service. According to the 2006 audit, the Courts Division of Manitoba Justice supplied incomplete information on the disposition of offences and collection of fines to the police. This can impede the ability of the police to provide accurate information in the annual reports provided to the Province. In the last few years however, the information provided by the Courts Division has been detailed and accurate.

The Winnipeg Police Service considered the use of claims data from Manitoba Public Insurance (MPI) along with crash data from the City to select sites during the planning stages of the program. However, MPI claims data are difficult to merge with the police collision data. Each data set is collected for a different purpose — each data set contains very different information and different variables and different definitions, making analysis challenging. For example, the exact location of collisions was not collected by MPI prior to 2002, limiting the usefulness of the data in correlating collision locations with collision severity to select the sites for photo enforcement. Also, MPI collects crash location information as part of its claim reporting process, and in doing so, relies on the claimants involved to provide the specifics of where the collision happened.

In addition, MPI claims data also do not contain information on the collision configuration in a standardized format suitable for analysis (e.g., rear-end, right-angle) which is an important distinction given that research has clearly demonstrated that different types of collisions are affected differently by photo enforcement. Hence, MPI claims data provide an incomplete picture for the purposes of evaluating Winnipeg's photo enforcement program.

It warrants mentioning that Winnipeg Police Service and MPI staff are working closely to identify opportunities to potentially augment MPI data, which can help provide additional insight into the effectiveness of the program.

**3.4.8 Legal challenges**

Overall, Manitoba Justice and the courts experienced minimal effects with the introduction of the Winnipeg Photo Enforcement Program. However, some challenges were encountered as is expected with the introduction of a new program and these are described in more detail below.

The main issue that affected the courts relates to the signage associated with construction zones and the manner in which tickets were issued. From January 2008 through to April 2009, approximately 60,000 Manitobans were issued tickets in construction zones. Many of these drivers were going between 72 and 76km/h where the speed limit is usually 80km/h. The issue relating to the ticketing of drivers stemmed from the requirement that workers be present at construction zones when ticketing occurred. However, tickets were also being issued during periods when there was no construction ongoing and/or when no workers were present. The result of this legal challenge was that in February 2009, a Judicial Justice of the Peace ruled that speed cameras could be used in construction zones only when workers are present. Manitoba Prosecutions Service undertook an appeal on the basis that the legislation did not require that workers be present but before it could be heard the signage issue identified. Subsequently, a Court of Queen's Bench Justice overturned the decision of the lower court.

This issue appears to have occurred due to a conflict regarding the signage at construction zones. While the provincial legislation defined a construction zone as an area with a sign indicating its beginning and one indicating its end, it was the practice of the Public Works Department to use signage that was consistent with the Manual of Uniform Traffic Control Devices for Canada, which states that the end of a construction zone can be indicated by simply an increase in speed. The Crown subsequently determined that the Winnipeg Police Service was not meeting the requirements of the legislation and signage was required to be added to the end zone of the construction areas. This issue serves to illustrate some of the challenges associated with police deployment of photo enforcement within construction zones. The temporary nature and conditions of construction zones can vary for several reasons, making it difficult for the police to ensure that all conditions are consistently present when photo enforcement is used at that location.

Following this ruling, the week of May 8, 2009, the Manitoba government suspended photo radar in construction zones pending the review of the outstanding tickets. This review was initiated a few weeks later. It was determined that a total of 867 tickets that had not yet been paid would instead be cancelled. However, with regard to the 60,000 tickets that had been previously paid, the then Attorney General stated that these monies would not be refunded. For those individuals that had pled not guilty to the offence and had a case pending, the charges were stayed.

This resulted in considerable negative publicity for the program as those who had pled guilty and paid the fines would not be reimbursed. These individuals were dissatisfied with this outcome and this led to a public petition on June 9, 2009. What was not well known was that the Summary Convictions Act states that a “guilty” plea and conviction is entered against a person who voluntarily pays a fine. Hence, payment of the fine is considered admittance of guilt and, from a legal standpoint, there was no basis to refund the money.

This issue sparked controversy with regards to where enforcement was meant to take place. To address the issue of photo enforcement in constructions zones the Winnipeg Police Service issued a press release, on May 20, 2010, outlining that photo radar will not be used in construction zones that have signs indicating a maximum speed when workers are present. They stipulated that they would only be used where there is a “Roadwork” sign at the beginning of the zone with a 60km/h speed limit sign and have a “Construction ends” sign at the end of the zone. The legislation is quite specific with regards to this topic. An Example of a typical enforced construction zone with proper signage can be found at http://justslowdown.ca/photo-enforcement/construction-zones/.

There was much negative press coverage of this construction zone signage issue and there were concerns that this may influence the public's perception of the program, and reinforce the view that the program was merely a revenue grab. Given that this issue reached its height in January 2009 when there was limited construction due to the winter weather, and because it was resolved fairly quickly, public opinion surveys about the program continued to show high levels of support among the public.

There was only one other legal challenge that was noted in relation to the photo enforcement program. On July 19, 2005, six residents of the Riel community of Winnipeg argued that the offence notices for photo enforcement were not sufficiently bilingual. The minister responsible for French language services announced that the Province of Manitoba would work with the City of Winnipeg to ensure the tickets issued in Riel would be fully bilingual. To address this issue, ACS made a minor IT change to their ticketing software so that offence notices could be produced in French. ACS indicated that this was an important and beneficial change to the program and helped them to improve their operations.

#### 3.4.9 Public awareness

An important element of road safety programs is public awareness. The success of Winnipeg's Photo Enforcement Program depends on the ability to inform the public about the dangers of red-light running and speeding and the benefits of photo enforcement. This is especially true if a change in driving behaviour is an expected outcome of the program. Public awareness initiatives are also important to address misperceptions about the program as well as to counteract incomplete or inaccurate information that is disseminated about the program.

Under the Conditions of Authority agreement, rigorous and continuous public awareness efforts were required to ensure the public is fully aware of and educated about the program and its safety benefits. This was deemed important given the low levels of public support for the program that had been experienced in other jurisdictions. As such, public awareness initiatives were a requirement of the contract entered into with ACS. In addition, the Conditions of Authority agreement also stipulated that the City was to erect permanent signs at entry points to the city including the airport, bus terminal and train station, advising that traffic laws may be photo enforced. Signs were also to be erected on primary streets of the City which are frequently monitored by photo radar and at approaches to intersections where there are red-light cameras to ensure that visitors to the City were equally aware of the program.

To provide the public with an opportunity to become aware of the program, prior to issuing tickets the City implemented a two-month warning period. During this phase, and for one month following the beginning of the issuance of tickets, the City conducted a multi-media public awareness campaign. This campaign was also continuously maintained post-implementation. The City was also required to inform the public about the specific locations of intersection cameras and general locations of the photo radar units.

However, prior to the implementation of the program, it was decided that signs would not be placed at the exact locations where mobile radar units are set up, comparable with practices in other jurisdictions. The reason for this was to avoid having drivers slow down for a short distance immediately in advance of the camera and then resume driving at an excessive speed. This would negate one of the objectives of the program. It was reported in other jurisdictions that drivers are more likely to modify their behaviour when signs are not deliberately placed at enforcement locations.

A variety of public awareness initiatives were utilized including advertisements on radio, television, billboards, moving advertisements, competitions (e.g., video contest for youth) and a website (www.winnipeg.ca/police/safestreets/). These were intended to heighten awareness of the dangers of speeding and red-light running and the benefits of visible, effective enforcement.

In 2008, awareness initiatives were expanded and became more targeted. This was made possible through the additional funds that the service provider, ACS provided to this effort as part of their contract extension. For example, the police used excerpts from a full webisode that was produced on photo enforcement for television to drive people to the website to see the entire video. This was successful in generating interest, particularly among youth, and an increase in users of the website was recorded. Statistics for the number of visits to the website have shown high interest in the program with over 6,000 views for the month of December, 2010. The website also included a chat wall with testimonials. To date, the majority of the comments posted have been supportive of the program.

### 3.4.10 Public support

Overall, public reception to the program has consistently been very positive. According both to public opinion polls conducted by the Winnipeg Police Service (in 2006, 2008 and 2010 — see Wyman 2006, 2008 and Winnipeg Police Service 2011) and the public opinion poll conducted by TIRF (in May 2009 — see section 4 of this report), a consistent majority (approximately 80%) of the public in the City of Winnipeg approve the use of red-light cameras and mobile photo radar. These surveys also revealed that public concern about red-light running and speeding was high. Efforts to increase public support for the program included the addition of a series of frequently asked questions to the website to address public concerns. Also, a telephone line was set up for the public to call in with questions or concerns about the program.

Although support for the program is high, it is noted that a small percentage of the public misperceive that the program has an underlying financial motive and are generally not supportive of the program. This view appeared to become more pronounced during the period at which the public was made aware that the persons manning the mobile radar vehicles are not regular police officers. There is also a small minority who continue to be unsupportive of the photo enforcement program in Winnipeg.

Another issue that may contribute to the public misperception that the purpose of the program is to generate money stems from strict requirements in legislation regarding how mobile enforcement is to be deployed. Mobile radar in Manitoba is limited to school zones, playgrounds and construction zones. During the period that drivers were inappropriately ticketed within construction zones, this misperception appeared to be more visible.

Media reporting is believed to have played a role in the level of public support that is evident for the program. Generally, media reports about the program have been consistently fair and balanced. Media reports frequently contain good information about the program and have accurately conveyed the goals and objectives of the program to the public. A minor number of reports have placed more emphasis on the perspective that the program is designed to generate revenue. The issue pertaining to signage at construction zones did receive heavy coverage and there was concern that it would diminish support for the program. Fortunately, this issue did not last long, as public opinion surveys conducted following this period did not indicate a decline in public support for the program.

With regard to those individuals that were issued a ticket, there have been some complaints made to the Winnipeg Police Service. In a majority of cases, once the photo enforcement program is explained, only a small percentage of drivers will challenge the ticket in court. The vast majority of drivers simply pay the tickets, suggesting general agreement with the program.

**3.4.11 Revenues and expenses**

It was expected from the outset of the program that the Province could experience an increase in revenue due to photo enforcement. It was the recommendation of the Working Group to adopt parameters to manage any surplus revenues from photo enforcement by reinvesting it in other traffic safety initiatives. In part, this recommendation was designed to address potential concerns among the public that the purpose of the program was to generate revenue.

All of the revenue generated by the program flows through the courts for disbursement to the City of Winnipeg. The City of Winnipeg receives 100% of the fine amount for offences under the Highway Traffic Act. Costs and surcharges associated with the fines are paid into general revenues for the Province of Manitoba with the portion for Victims of Crime being held in a separate trust.

The amount of revenue that is generated is dependent of several factors, including the number of photo enforcement tickets that are issued, the percentage of drivers who voluntarily pay the ticket, and the amount of the fine (related to excess of speed). For example, in construction zones, fines range from $260 to $2,125. For speeding 10km/h over the speed limit, tickets are $177.50, ranging up to 99km/h over the limit in which the tickets are $1,308.25. Surplus revenue is incorporated into the overall Winnipeg Police Service budget to fund other policing activities.

Program revenue was generally steady each year. In 2008 there was a spike in revenue due to a large amount of construction taking place that year. Since 2008, revenue has again leveled off and continues to be consistent. It should be noted that enforcement activities are somewhat weather dependent given that limited construction zones are evident in winter months.

Initially, the Steering Committee projected a healthy revenue stream for the program, resulting in high expectations for revenue before the program was implemented. These calculations were challenging due to the uniqueness of Winnipeg's program. In particular, Winnipeg's decision to implement benchmarks with the service provider based upon a flat fee rather than a cost per ticket occurred in part to avoid the perception that the City benefits financially from each ticket that is issued. It was felt that this sent the wrong message to the public about the purpose of the program. However, this made revenue projections difficult to ascertain because there were no comparable programs in other jurisdictions.

In addition, the pilot project had not yet been completed when projected revenues were estimated which limited the ability to properly predict the number of offence notices that could be issued within the first five years of the program. Thus, there was a shortfall in the program revenue generated versus what was originally projected ($95 million over first five years). This occurred in part because a significantly lower volume of offence notices were issued than anticipated. Thus, as a consequence of the nature of the initial contract with the service provider, the low volume of offence notices resulted in increased program costs. For this reason, the contract extension was modified to include a hybrid approach and mitigate the risk on the part of the City.

Ultimately, the financial goal of the program was to cover the costs of the technology. In this respect, the program exceeded this goal and generated a positive cash flow, enabling reinvestment in other police crime reduction initiatives. The expected revenue estimates for 2010, 2011, and 2012 have since been revised based upon this new contract and are lower compared to the initial projections.

#### 3.4.12 Compliance with external authorities

Overall, the program has been and continues to comply with external authorities (e.g., Conditions of Authority agreement and provincial legislation) and no major problems have been encountered. Of note, the only apparent issue that emerged was that Canada Post did not like how ACS packaged offence notices that were mailed to the charged individuals. It was reported that these packages slightly exceeded the size for the mailing rate. To address this issue, ACS subsequently reduced in size the offence notice packages that are mailed.

### 3.5 Conclusions

Overall, the Winnipeg Enforcement program is innovative in how enforcement is being achieved. In general, the public have become more conscious that the cameras are in place.

Program operations appear to be smooth and issues that do emerge are easily resolved and dealt with accordingly. To illustrate, there were good working arrangements between the Winnipeg Police Service and the service provider, ACS and there was good communication among all agencies. The situation of Winnipeg Police Service administrative/clerical staff in the ACS building greatly facilitates communication between the two agencies. In addition ACS has been very responsive in addressing any issues that were brought to their attention by the Winnipeg Police. Staffing and workload issues have also been generally manageable with little staff turnover.

There are however some issues that will require ongoing attention. First, there is a need to transition to digital technology. In order for this to occur a change in legislation will be required to support this transition. Other issues that will require ongoing consideration include the monitoring of revenues relative to projections; the continued monitoring of public support; and emphasis on awareness initiatives targeted towards high-risk populations.

### 3.6 Recommendations

The lessons learned during the implementation of any program or policy can be useful to improve existing programs or to guide the planning and implementation of future initiatives. Recommendations based upon the outcomes of the process evaluation of Winnipeg's photo enforcement program are presented and discussed in more detail below. Some of these recommendations are specific to Winnipeg whereas others can be useful to other jurisdictions that are considering the development and implementation of a photo enforcement program.

### 3.6.1 Recommendation 1

**Improve the documentation of key program decisions and their associated decision-making criteria.** Clear documentation of decisions and the criteria on which such decisions are based can serve some important purposes. First, official documentation by agencies of decisions involved in any implementation is important to guide staff activities and create accountability. For example, while Provincial legislation and regulations typically contain much policy direction regarding program procedures and practices, it is important that relevant decisions are also articulated at an operational level. In this case, the selection of intersection safety camera sites was largely guided by Provincial legislation. However, other practical factors were also necessarily considered as part of the site selection process although they were not stipulated in legislation. These included: public concerns about crash locations, the presence of street furniture and an appropriate power source, data pertaining to high-crash locations, and the level of safety to conduct photo enforcement.

Second, agencies may also benefit from such documentation as a strategy to promote consistency in operations. This may be particularly important in the event that programs encounter staff turnover at either managerial or operational levels; or on the part of the service providers.

Third, the documentation of decisions can further increase program transparency among political officials and the public. This may contribute to higher levels of political and public support for the program.

Finally, the ongoing documentation of key decisions and progress regarding the implementation of a program as well as timelines, can facilitate and support a rigorous program evaluation.

### 3.6.2 Recommendation 2

**Seek external input regarding financial projections associated with the program.** The amount of revenue that is generated by a photo enforcement program can be dependent upon several factors related to the nature of the contract that is entered into with the service provider. Such factors may include the number of photo enforcement tickets issued; the percentage of drivers who voluntarily pay the ticket versus challenge the ticket in court; and, the amount of the fine that is ultimately collected. Other important considerations include the magnitude of the program, staffing, the costs of technology over time, and associated program costs. Accurate program projections are needed to ensure that local governments are well-positioned to appropriately allocate resources, to manage risk, and to inform broader financial decisions.

In the case of Winnipeg's program, financial projections were difficult to gauge. Prior to implementation, a healthy revenue stream was initially projected for the program, resulting in high expectations for program revenue. These calculations were challenging to undertake due to the uniqueness of Winnipeg's program, i.e., there were no comparable programs in other jurisdictions that could be used as a baseline or measure on which estimates could be based. This resulted in projections being over-estimated.

The expected revenue estimates have since been revised in the new contract and are lower compared to the initial projections. In order to ensure that the projection method is sound, it is recommended that Winnipeg Police Service and the City of Winnipeg seek expert input on future financial projections for the photo enforcement program.

### 3.6.3 Recommendation 3

**Enhance program partnerships to improve existing data sources or to make available new data sources that can augment program measures and provide additional information regarding the photo enforcement program.** Multiple data sources and measures of a photo enforcement program are required to properly manage, evaluate and improve the effectiveness of the program. At present, the Winnipeg Police Service does rely upon multiple types of data to provide insight into and increase understanding of program operations, including program reports containing data from cameras that are produced by ACS, police crash data, and data from Manitoba Justice.

There may be additional sources of data that can potentially provide a different window on the use of photo enforcement, such as insurance data. This is assuming that insurance data sources are made available and that any data are collected in a manner that specifically facilitates insight into red-light running or speed related crashes. However, the usefulness of such data will be a function of the level of detail associated with the data and the ability of researchers to isolate particular variables within the datasets to conduct meaningful analyses.

In the case of Winnipeg's photo enforcement program, consideration was given to the use of insurance claims data collected by Manitoba Public Insurance (MPI). For example, during the site selection process, the potential to use MPI claims data in conjunction with City of Winnipeg crash data during the planning stages of the program was explored. However, this option was not feasible because it was challenging to merge MPI claims data with Winnipeg crash data. Of particular importance, the MPI claims data do not contain information on the collision configuration in a standardized format suitable for analysis, which is an important distinction given that research has shown that different types of collisions are affected differently by photo enforcement, i.e., it would not be possible to distinguish between red-light crashes and all other types of crashes that are not influenced by photo enforcement. Hence, MPI claims data provided an incomplete picture for the purposes of evaluating the program.

The Winnipeg Police Service and MPI are working closely to identify opportunities to potentially augment the collection of MPI data. As such, it is recommended that the Winnipeg Police Service continue to work with MPI to improve available data sources for both the management and evaluation of the program.

#### 3.6.4 Recommendation 4

**Augment performance measures associated with the photo enforcement program.** Clearly defined performance measures can facilitate and support the management and evaluation of a program. Performance measures should serve as objective indicators of what a program is trying to accomplish and what is being achieved. The routine collection of such data has many purposes including, the monitoring of day-to-day operations, demonstrating quality assurance, early identification of potential problems, and ultimately program evaluation. In the short and the long-term, these data are useful to inform refinements to the program and potential improvements.

The Winnipeg Police Service currently uses a variety of performance measures for these purposes (e.g., average speeds at intersections, number of visitors to website, number of red light violations, and public opinion about the program). Augmenting existing performance measures with additional program measures is recommended to increase understanding of the program and provide new windows on its operation. Examples of additional measures may potentially include: the number of tickets that are challenged in court; the amount of court time required to process a case; the time it takes for a case to get to court; and, reasons why people challenge the tickets.

### 3.6.5 Recommendation 5

**Explore the feasibility of and level of support for strategies to transition to digital technology.** The Winnipeg Photo Enforcement Program currently uses analogue (wet film) technology for both mobile and intersection camera systems. This has been identified as a potential issue that may have to be addressed in the future. This is due to the fact that digital cameras have become widely available for the purposes of photo enforcement. More jurisdictions have made the switch to digital technology and, as a result, fewer manufacturers are continuing to make analogue technology (utilizing wet film) available. If this trend continues, at some point Winnipeg will no longer be able to access wet film for use in its program.

The ability of Winnipeg to continue its photo enforcement program will require a transition to digital camera technology in the future. The Winnipeg Police Service is aware of this issue and is currently exploring options, feasibility and costs of making this transition in the future so that they may be prepared to manage this change if needed. ACS has agreed to work with the Police Service in the event of any transition so that it would be cost-effective and not result in interruptions in service.

An important consideration of such a transition is the need for a change in legislation to permit the transition to the use of digital equipment. A legislative amendment would be required to support this change in program operations. In the event that agreement on a legislative amendment is not reached, and wet film is no longer available, then the program would not be able to continue operations. Hence, it is recommended that the transition to digital technology be explored so that informed decisions can be reached and, if needed, a reasonable plan and timelines can be developed to effectively manage this transition.

### 3.6.6 Recommendation 6

**Consider a review of photo radar locations on an ongoing basis and in relation to conditions set out in legislation.** It would be useful to regularly review what is happening at individual locations to determine the ongoing suitability and need for photo enforcement at specific locations. This review should include an examination of the level of violations and crashes at specific intersections, any changes to street furniture, road traffic or construction, reported concerns from citizens regarding high-crash locations, feedback from the service provider, balanced use of cameras throughout a jurisdiction, and other relevant considerations. Such a periodic review will provide additional insight into program operations and may serve to identify appropriate modifications to the program (examples of strategies to select sites are available in the literature).

On a larger scale, a periodic review of photo enforcement legislation may also be warranted to also review criteria associated with camera locations. Although Winnipeg's photo enforcement program is managed and delivered by the Winnipeg Police Service (and the City), the program is enabled by provincial legislation. Thus provincial legislation sets out the conditions under which the program is regulated and the criteria for locations in which photo enforcement may be employed. There are strict requirements in Provincial legislation regarding how mobile enforcement is to be deployed. Mobile radar in Manitoba is limited to school zones, playgrounds and constructions zones. This was decided, in part, to ensure that the program focused on and emphasized improved safety as a primary goal, and was not misperceived by the public or others as merely a source of revenue. The City of Winnipeg and the Winnipeg Police Service must manage the program according to these requirements.

There have been some unintended negative consequences associated with these criteria relating to the selection of photo enforcement locations. One consequence involved challenges for Winnipeg Police Service to deploy units in accordance with the strict requirements of the legislation (e.g., ensuring all conditions associated with construction zones were being achieved). Another consequence involved challenges in determining financial projections for the program. Fewer jurisdictions specifically limit in legislation the locations at which photo enforcement may be conducted, resulting in limited comparable jurisdictions on which projections could be developed, all other factors being equal.

Thus, a periodic review of the decision to limit photo radar to only specific locations is recommended. Results from this large-scale evaluation can be used to inform knowledge about program effectiveness, provide a range of insights into the different aspects of program operations, and provide a sound basis for decision-making.

# 4. PUBLIC OPINION POLL

## 4.1 Introduction

Public attitudes towards speeding and red light cameras can have a significant influence on the success or failure of these programs (Chen et al. 2000). Although drivers may reduce their speed and obey traffic signals in order to avoid apprehension, negative public attitudes may counteract the immediate benefit and even inspire defiance of traffic laws. Thus, when evaluating the success of a photo enforcement program, it is essential to understand public attitudes towards these programs. Also, it may be beneficial to increase public awareness of photo enforcement programs and their benefits in an attempt to increase positive attitudes. As such, a public opinion poll was conducted as part of the evaluation of Winnipeg's photo enforcement safety program.

## 4.2 Methods

### 4.2.1 Procedure

A public opinion poll was conducted in the month of May, 2009. The questionnaire included a set of demographic questions and a set of items designed to provide information on attitudes, opinions, and behaviours about Winnipeg's photo enforcement safety program (a copy of the questionnaire is in the appendix to this report). The survey required an average of approximately 5 minutes to complete. It was administered by telephone by Opinion Search Inc. (using random digit dialling) to a representative sample of 750 respondents from the Winnipeg Census Metropolitan Area (CMA).

Criteria for inclusion were: having a valid driver’s licence and having driven in the past 30 days. To minimize bias due to refusal to participate up to eight call back attempts per sample record were carried out. Also, when the interviewer introduced the survey, it was explained that personal information would be kept confidential and the answers would be treated anonymously. Sponsorship was revealed such that participants knew that the nature of the survey was non-commercial. The response rate was over 22% — given today's low response rates of around 10% for telephone surveys according to the Marketing Research & Intelligence Association (MRIA 2006), such a relatively high response rate may be indicative of a general interest in Winnipeg's photo enforcement safety program.

### 4.2.2 Participants

Half of the 750 drivers included in the sample were female (375) and the other half were male (375). The sample was weighted and stratified and included 500 Winnipeg residents and 250 residents from outside Winnipeg but within the Winnipeg CMA.

After weighting the sample, male respondents counted for 49% of the respondents and females for 51%. The age range was 18 through 90 years, while the weighted mean age was 46.3 (95%-CI: 44.9-47.6). The majority of the respondents were married or living with a partner (67.4%; 95%-CI: 63.8%-70.9%). The second largest group of respondents were single, never married (16.7%; 95%-CI: 13.8%-20.0%); the third largest group were separated or divorced (9.2%; 95%-CI: 7.3%-11.5%); and, finally about 6.7% were widow or widower (95%-CI: 5.1%-8.6%).

The majority of respondents had not been involved in a traffic collision in the past 12 months (89.4%; 95%-CI: 86.8%-91.6%), while 57 respondents (8.3%; 95%-CI: 6.4%-10.7%) reported having had one traffic collision in the past 12 months, 18 respondents reported two collisions in the past 12 months (2.2%; 95%-CI: 1.4%-3.5%) and one respondent reported having been involved in three collisions in the past 12 months. About 27% (95%-CI: 24.0%-30.6%) said they have previously been injured in a motor vehicle accident counting only injuries that required medical attention.

Finally, when asked about the number of traffic tickets in the past 12 months, parking tickets excluded, 83.0% (95%-CI: 80.0%-85.7%) answered they had had none, 12.6% (95%-CI: 10.3%-15.3%) answered one, 2.9% (95%-CI: 1.8%-4.6%) answered two and the remaining 1.5% (95%-CI: 0.8%-2.7%) answered between three and seven.

### 4.2.3 Questionnaire

A series of closed-ended questions were designed to probe the respondents' attitudes, concerns, and self-reported behaviour about several issues including speeding and red-light running. A variety of formats were used with the items in the questionnaire. Several used a six-point Likert-type scale, for example, in gauging the respondent's level of concern about the problem (where one meant the respondent thought it was not a problem at all and six meant he/she thought it was an extremely serious problem). When the objective is to determine how people are leaning on an issue, it is advised to not use middle categories (Gray and Guppy, 2003). Also, note that only the extremes of the scales were labelled, as respondents may not remember all possible responses after they are being listed (Woodward and Chambers, 2005). Other questions/items used a dichotomous format, for example, when asking whether the respondent believes the safety program helps improve road safety in Winnipeg or not. Demographic questions included items such as age, gender and marital status.

#### 4.2.4 Data analysis

Stata, release 10 was used to calculate univariate frequency distributions, 95% confidence intervals (95%-CI) and Chi-square statistics taking account of the stratified and weighted sampling design (see StataCorp. 2007 for details about the modeling procedures). Also, multivariate logistic regression in Stata was performed, accounting for design effects of the used sampling design and controlling for a variety of variables, including demographic variables such as gender, age, mileage and family status, and other variables, such as the number of collisions the respondent had been involved in previously (i.e., in the past 12 months). Based on a sample of this size, on average, the results can be considered accurate within 3.6%, 19 times out of 20.

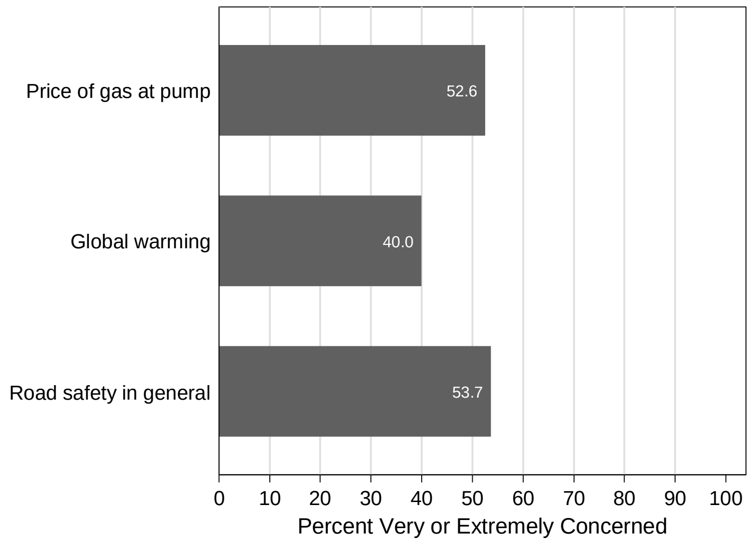
### 4.3 Results

#### 4.3.1 Concern about social issues and road safety issues

Before asking respondents specifically about their opinions regarding the photo enforcement safety program, two sets of generic questions regarding concern about a variety of topics were asked. This was done to gauge how concerned respondents are about road safety in general and about speeding and red-light running in particular to help provide context to interpret the results.

As can be seen in Figure 4-1, respondents were most concerned about road safety when compared to the price of gas at the pump and global warming. About 54% said they are very or extremely concerned about road safety (95%-CI: 49.9%-57.4%) and a slightly lower percentage of respondents said they were concerned about the price of gas at the pump (95%-CI: 48.8%-56.3%) — note that the difference between both is negligible. Fewer respondents said they were concerned about global warming (95%-CI: 36.4%-43.7%) — the difference between this issue and the two other issues is significant.

**Figure 4-1:** Percentage very or extremely concerned about social issues

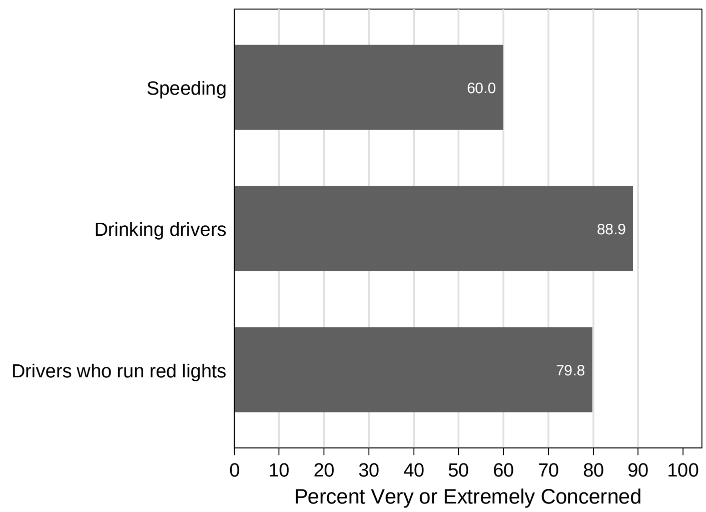



The low percent for global warming is notable as well as the fact that the percent attesting to be concerned about road safety is comparable to what TIRF polls (and others such as the poll conducted by EKOS research) typically reveal. For example, according to TIRF's 2008 Road Safety Monitor (RSM), an annual public opinion poll that gauges the opinions of Canadians, about 58% of respondents were very or extremely concerned about road safety (TIRF 2008). With such a percentage being concerned about it, this ranked road safety as a secondary, mid-level priority, behind such issues as pollution and before issues as airline safety.

When looking at Figure 4-2, it becomes clear that the issue of drinking drivers is of most concern to the respondents with almost 90% expressing high levels of concern about it (95%-CI: 86.3%-91.1%). Comparable patterns regarding concern about drinking driving have also been found elsewhere and typically this issue ranks as the number one concern (see e.g., TIRF 2008 and Vanlaar et al. 2007). Clearly, most respondents (about 80%) are also concerned about drivers who run red lights (95%-CI: 76.6%-82.7%), albeit to a lesser extent than about drinking drivers. Finally, respondents seemed to be the least concerned about speeding, compared to the other two issues, with only 60%

expressing high levels of concern (95%-CI: 56.2%-63.6%). Again, these patterns are comparable to findings from other, independent sources.

**Figure 4-2:** Percent very or extremely concerned about road safety issues




**4.3.2 Knowledge about the Winnipeg photo enforcement safety program**

Respondents were asked whether they knew "that the city of Winnipeg runs a photo enforcement safety program to increase road safety in Winnipeg by reducing the number of speeding and red light violations". About 95% (95%-CI: 93.0%-96.4%) confirmed they knew about this program, which means that virtually everybody in the Winnipeg CMA is aware of it.

Table 4-1 shows how people found out about the program. As can be seen, the majority of respondents found out about it through the news on the radio or TV (80.4%) or by noticing traffic signs in the street or at intersections indicating automatic speeding and red-light running enforcement is taking place (79.7%). Also, still about 65% (64.7%) read about it in the newspaper. Of interest, 28.5% admitted they found out about the photo enforcement program because they were caught speeding and received a ticket, while about 4.5% were caught running a red light and received a ticket.

**Table 4-1:** Percentage indicating how respondent found out about the Winnipeg photo enforcement safety program

| *How did you find out about the program?* | *Percent* |
|---|---|
| Heard about it in the news on radio or TV | 80.4 (77.1%-83.3%) |
| Noticed enforcement signs in street or intersection | 79.7 (76.4%-82.7%) |
| Read about it in newspaper | 64.7 (60.9%-68.3%) |
| Heard about it on TV in an advertisement | 41.6 (37.8%-45.4%) |
| Heard about it from a friend or relative | 28.9 (25.5%-32.6%) |
| Was caught speeding and received a ticket | 28.5 (25.1%-32.1%) |
| Read about it on the Internet | 10.5 (8.3%-13.2%) |
| Was caught running a red light and received a ticket | 4.5 (3.2%-6.2%) |

Those respondents who were caught (28.5% for speeding and 4.5% for running red lights) were also asked how many times they were caught and received a ticket. The answers appear in Table 4-2. Both for speeding and running red lights the majority of respondents who were caught, were only caught once (59.4% and 82.4% respectively).

**Table 4-2:** Percentage of number of times caught speeding and running red lights

| *Number of times caught* | *Speeding* | *Running red lights* |
|---|---|---|
| Once | 59.4 (52.1%-66.4%) | 82.4 (64.4%-92.4%) |
| Twice | 26.5 (20.6%-33.3%) | 10.8 (4.0%-26.0) |
| Three times | 8.4 (5.3%-13.2%) | 2.5 (0.3%-17.4%) |
| More than three times | 5.7 (3.0%-10.6%) | 4.2 (0.5%-26.6% |

Based on these results, it appears that speeding is a more common infraction than running red lights (28.5% were caught speeding versus 4.5% running red lights) and also a more persistent one, as more respondents have been caught twice and three times for speeding than for running red lights. This is in line with expectations.

Finally, 33 respondents answered "other" (category not shown in Table 4-1). Most of these answers were either that they had learned about the program because a family member or friend was caught and received a ticket or because they had seen the actual cameras or the vehicles equipped with the photo radar at playgrounds and schools, rather than the signs.

### 4.3.3 Opinions about the Winnipeg photo enforcement safety program

Respondents who had previously indicated they had heard of the Winnipeg photo enforcement safety program (714 out of 750) were also asked about their opinions about it. The questions they were asked included:

Do you believe the program helps improve road safety in Winnipeg?
Do you believe the program makes the public more aware of the issue of speeding?
Has this road safety program affected your own driving behaviour?
Do you support the continuation of this program?

With respect to the first question, 71.1% (95%-CI: 67.4%-74.4%) confirmed they believe the program helps improve road safety in Winnipeg. Note that 30 respondents or about 4%, did not provide an answer for this question because they did not know the answer or because they simply refused to answer.

About 80% of the respondents (80.6%; 95%-CI: 77.3%-83.4%) thought the photo enforcement safety program makes the public more aware of the issue of speeding. This time, only 17 respondents or about 2% did not provide an answer.

Respondents were asked to answer the third question about their own driving behaviour using a set of items, each of which could be answered with a simple yes or no. The first item was "I slowed down in traffic because of this program" and 37.9% (95%-CI: 34.3%-41.7%) of respondents agreed with this. The second item was "I have become more cautious when crossing an intersection because of this program"; 40.3% (95%-CI: 36.6%-44.1%) agreed. The third item was "I have become a better driver overall because of this program". This time, 26.8% of respondents (95%-CI: 23.6%-30.3%) agreed. Note that all 714 respondents who know about the Winnipeg photo enforcement safety program provided an answer for these items; no one refused to answer.

Finally, 81.3% of respondents support the continuation of the photo enforcement safety program (95%-CI: 78.2%-84.1%). Keeping the boundaries of the 95%-CI in mind, this means that we can be 95% certain (or 19 out of 20 times) that the true percentage of people living in the Winnipeg CMA who support the continuation of this program lies between 78% and 84%.

A comparable set of questions was used with those respondents who had indicated they did not know about the photo enforcement safety program (36 out of 750). First the program was explained to them using the following description:

"The photo enforcement program in Winnipeg was established in 2003 to enhance road safety in the city by using camera enforcement to reduce the number of speeding and red light violations. The Winnipeg Police Service uses cameras at 48 locations and mobile radars to catch drivers who speed or run red lights."

Then, the following questions were asked:

- Do you believe this program helps improve road safety in Winnipeg?
- Would such a program have affected your own driving behaviour in traffic if you had been aware of the program?
- Do you support the continuation of this program?

While these questions may be somewhat challenging to someone who is not familiar with the program, the answers to these questions do provide insight — at least to some extent — into the opinions about, and support for the photo safety enforcement program among those who have not yet been exposed to it.

About 77% of these respondents (77.3%; 95%-CI: 58.6%-89.1%) answered they believe the program helps improve road safety in Winnipeg. Even though they have yet to be exposed to this program, 44.2% (95%-CI: 27.5%-62.3%) believe that such a program would have affected their own driving behaviour in traffic if they had been aware of it. Hypothetically speaking, these ones could be counted among the group who is aware of the program and who did confirm it changed their own driving behaviour, which could increase this group by a few percent points.

Finally, 88.4% (95%-CI: 73.2%-95.5%) support the continuation of the program. However, this percentage might be lower if they would have been exposed to the program because of speeding or red-light running behaviour and they received a ticket as a result of it.

### 4.3.4 Profile of supporters and opponents

A multivariate analysis was conducted to investigate the profile of respondents who support the continuation of the program versus those who oppose it. Both groups were identified using the answers to the question "do you support the continuation of this program?". Note that only respondents who had previously answered they knew about this program have been included in these analyses (714 respondents out of 750). The reason for this it that we cannot be sure that those who said they did not know about the program would actually truly support it or not in case they would have known about it. For example, as suggested above, some of those who have not yet been exposed to the program might become exposed to it as a result of a traffic violation. In this case, receiving a ticket might decrease their support for the program, even if hypothetically speaking today they believe they support it.

The following six variables were found to have a significant influence on support for the program:

Concern about road safety in general;
Concern about speeding in particular;
Having been caught and having received a ticket for speeding before;
Believing the program helps improve road safety in Winnipeg;
Believing the program makes the public more aware of the issue of speeding;
Age.

Regarding the first variable, it was found that being concerned about road safety in general increases the likelihood that people will support the program. To illustrate, out of all respondents who are concerned about road safety in general, 87.2% support the continuation of the program, while out of all respondents who are not concerned about road safety in general, only 74.6% support the continuation of the program.

A comparable, yet somewhat more pronounced effect was found with respect to being concerned about speeding in particular. More precisely, out of all respondents who said they were concerned about speeding, 89.1% support the continuation of the program. This percentage was only 70.0% among those who are not concerned about speeding. Note that no comparable effect was found with respect to being concerned about running red lights.

Perhaps not surprisingly, those people who learned about the photo enforcement safety program because they were caught speeding and received a ticket are less supportive of the continuation of the program. Among those who have been caught and received a ticket, 74.3% support the continuation; among those who have not been caught before, 84.2% support the continuation. While having been caught and received a ticket clearly increases the likelihood that people will be less supportive of the continuation program, it warrants mentioning that still about 74% of those who have been caught are also supportive of the continuation of this program.

The strongest supporters of the continuation of the program are those who believe the program helps improve road safety in Winnipeg. More than 97% (97.4%) of those who believe this, support the continuation of the program, which basically means that if people believe the program improves road safety in Winnipeg, they will support it. On the other hand, only 39.3% of those who do not believe the program improves road safety in Winnipeg support the continuation of it. Clearly, if you can convince a person that the program has a positive influence on road safety, that person will likely become supportive of the continuation of the program.

Another strong, albeit less pronounced effect was found among those who believe the program makes the public more aware of the issue of speeding. If people believe the program does make the public more aware of the issue, they will more likely support the continuation of the program (89.1% of those who believe this, support the continuation of the program versus only 46.3% of those who do not believe this).

Finally, the youngest age group (18 to 34) was found to be most supportive of the continuation of the program: 85.0% of all 18 to 34 year old respondents support it. Both older age groups (35-54 and 55+) were found to be less supportive in the multivariate analysis. However, when looking at a cross tabulation between age and support only (i.e., not controlling for the other confounding variables), respondents aged 35-54 still seemed to be less supportive (76.0%), while the level of support among the group 55+ was comparable to that of the younger age group (84.7%).

## 4.4 Conclusions

The levels of public concern about road safety in general and specific road safety issues in particular in this study are in line with levels of public concern coming from other independent sources. This speaks to the credibility of the results from this study.

Also, while people living in the Winnipeg CMA ranked road safety before global warming (note that the difference with the price of gas at the pump was not significant), the actual percentage of respondents being concerned about it (54%) is indicative of road safety being considered to be a mid-level priority to the public. Furthermore, when looking at specific road safety issues including drinking driving, speeding and running red lights, a comparable conclusion can be drawn with respect to the issue of speeding. The public certainly is concerned about drinking driving and a clear majority is also concerned about running red lights, but fewer people seem to be concerned with speeding (60% reported being very or extremely concerned about speeding compared to 89% for drinking driving and 78% for running red lights). There seems to be a discrepancy between the levels of concern about speeding and the actual damage caused on the roads as a result of speeding.

While it appears there is a lower level of concern among the people in the Winnipeg CMA — predominantly about the issue of speeding — virtually everybody seems to be aware of Winnipeg's photo enforcement safety program. When asked whether they knew about the program, about 95% confirmed they did. Moreover, the program garners rather high levels of support among people from the Winnipeg CMA: 71% believe the program helps improve road safety in Winnipeg, about 80% think the photo enforcement safety program makes the public more aware of the issue of speeding, and, most importantly, 81% support the continuation of the photo enforcement safety program. Keeping the boundaries of the 95%-CI in mind, this means that we can be 95% certain (or 19 out of 20 times) that the true percentage of people from the Winnipeg CMA who support the continuation of this program lies between 78% and 84%. Also, it warrants mentioning that even among those who have previously been caught for speeding and received a ticket, the level of support for the continuation for the program is still high at about 74%.

Finally, between 26% and 40% of people actually believe they changed their behaviour due to the program, either by slowing down (38%), by becoming more cautious when crossing an intersection (40%), or by becoming a better driver overall (26%). Such high levels of support among the public cannot and must not be ignored.

On the other hand, when people were asked about their speeding and red-light running behaviour, 28.5% admitted they had previously been caught for speeding and received a ticket and 4.5% admitted they had previously been caught for running a red light and received a ticket. This means there are still a lot of people in the Winnipeg CMA who commit infractions. Ways to increase the effectiveness of the program among this population should be explored.

One way of increasing the program's effectiveness might be through the increase of support for the program. Ways of increasing support for the program were investigated in this study using a multivariate analysis into the profile of people in favor of the continuation of the program versus those who are against the continuation of the program. Several dimensions were identified that hold promise in terms of increasing support for the program. First, raising levels of concern about road safety in general and speeding in particular can serve as a lever to increase support for the program as it was found that being more concerned goes hand in hand with being more supportive of the program. Vanlaar et al. (2008) have previously identified several ways to affect levels of concern in order to encourage people to take action or become more involved. For example, if people believe that others are concerned about the issue, this will increase their own level of concern (this is known as "the bandwagon effect"); or, if people understand the risks associated with speeding and red-light running, they will likely become more concerned about it. According to the results of the current study, the expectation would be that the increased level of concern would then lead to a higher level of support for the continuation of the program. This would presumably result in more people abiding by the rules with less speeding and red-light running infractions as a result.

Second, if you can convince the opponents that Winnipeg's photo enforcement safety program helps improve road safety and makes the public more aware of the issue of speeding, levels of support for the continuation of the program among them would rise. This begs the question how those people who are against the continuation of the program can be convinced of this. To this end, a strategy could be developed that would use social marketing research findings about making people understand how risky these behaviours are and showing that the majority of people truly are concerned about these issues. Other potential dimensions of interest include the magnitude of the problem. People may underestimate the true magnitude of the problem so if they would understand what the true extent of the problem is, they may no longer underestimate it and become more concerned about it as a result; this would in turn lead to higher levels of support for the program.

It may also be useful to ensure that people who are caught and received a ticket — primarily for speeding although logic dictates the same would be true for running red lights — understand their behaviour is dangerous. It was found that having been caught and received a ticket influences the level of support. More precisely, among those who have been caught, support for the continuation of the program is lower. To actually make this subgroup aware of their dangerous behaviour may require a tailored approach because they may be less receptive of general social marketing strategies. Perhaps it could be investigated if and how this subgroup could be encouraged to be more cognizant of the risks they impose on other road users because of their behaviour. If they would understand why they are being punished they may better appreciate the consequences and would perhaps become more supportive. As a sidebar, it is likely not impossible that at least a portion of them would become supportive, as suggested by the finding that 74% of those who were caught indeed actually are supportive of the program. On the other hand, it is acknowledged that not all people who committed infractions will be receptive of such a strategy. There will always be persistent offenders with whom such a rational approach would not work. The results from this study confirm this as several respondents indicated they were caught for speeding and running red lights at least three times, indicative of persistent or 'hard-core' offenders.

Finally, it seems the age group 35-54 is the least supportive of the program. When developing a strategy to increase levels of support, this should be borne in mind.

# 5. TIME SERIES ANALYSIS

## 5.1 Introduction

This section contains the results from the time series analysis of crashes. Crashes that happened between January 1994 and December 2008 have been used in these analyses. Data come from the City of Winnipeg. Due to data limitations, claims data from Manitoba Public Insurance (MPI) have not been used in these analyses. More precisely, collection of crash location information in MPI's claims system only started in June 2002. Also, before 2007 it was not possible to distinguish between crashes that happened at intersections versus crashes that happened near intersections (for example in a parking lot next to the intersection). Finally, crash configuration information is not available in the claims data set in a standardized format suitable for analysis making it impossible to distinguish between different types of crashes such as right angle crashes and rear end crashes. Given the importance of having such information available for the duration of the entire evaluation period (i.e., 1994 through 2008) data from the City of Winnipeg have been used.

Two sets of analyses have been conducted, one set of analyses regarding crashes related to red light running, notably right angle crashes and rear end crashes and one set of analyses regarding crashes related to speeding, notably injury crashes and property damage only (pdo) crashes. Both sets of crashes further distinguish between crashes that happened at 48 intersections with photo enforcement (i.e., where cameras are used) versus crashes that happened in Winnipeg as a whole, excluding the camera intersections. Analyses of Winnipeg as a whole, excluding camera intersections have been conducted to investigate possible spill-over effects, i.e., to see if any effects of photo enforcement were apparent at other intersections where no cameras are used.

## 5.2 Methods

The general approach adopted to conduct the time series analyses is described below.

In each analysis, the pre-intervention series (i.e., the series of data before the first cameras were installed) was used to build the final ARIMA time series model, as suggested by McCleary and Hay (1980). Once the final ARIMA model was found, a set of dummy variables to model the intervention along with control group data have been inserted in the final model simultaneously to test the hypotheses about possible intervention effects of photo enforcement.[2]

Control group data come from data regarding comparable crashes at comparable times in the province of New Brunswick. During the monitoring period (January 1994 through December 2008) New Brunswick does not have photo enforcement (see CCMTA 2010). Also, New Brunswick was one of the few suitable jurisdictions that did not change the way crash configuration was captured during the monitoring period. Other jurisdictions did change this, which disrupted the time series and rendered them unsuitable for use as a control group. Furthermore, as Canadian jurisdictions, both New Brunswick and Winnipeg are subject to comparable macro-economic developments, which is another important consideration in support of New Brunswick as a control group. The total number of crashes in Winnipeg from 1994 through 2008 was 455,497 while the total number for New Brunswick was 282,057. The distribution of crashes according to injury severity in both jurisdictions is comparable with the large majority being property damage only (Winnipeg: 73%; New Brunswick: 62%), followed by injury crashes (Winnipeg: 26%; New Brunswick: 37%) and fatal crashes (Winnipeg: 0.2%; New Brunswick: 1%). Finally, by virtue of selecting crashes in New Brunswick based on crash configuration, the large majority of selected crashes took place on urban roads. As such, the selected data from New Brunswick are suitable as a control group for the city of Winnipeg.

Pre-intervention series of raw crash data have been investigated with special attention given to the overall pattern, outliers and variance of the data. Due to outliers and non-stationary variance, all series (eight in total — four about red light running and four about speeding) have been transformed using the natural log transformation to mitigate their impact. Sometimes the first part of a pre-intervention series has not been used because it differed too much from the rest of the series (this first part is then simply ignored for the entire analysis).

[2] It warrants mentioning that extensive efforts were made to obtain monthly counts of such variables as unemployment, population, traffic, etc. in Winnipeg for the monitoring period, but these data were not available.

The log transformed series have then been studied to see if local and/or seasonal differencing was required. Decisions about local differencing were based on a graph of the log transformed pre-intervention crash series and a formal test of a possible linear trend in the final ARIMA model (if such a linear trend was not significant this confirmed local differencing was not required). Decisions about seasonal differencing were based on a correlogram of the log transformed pre-intervention series.

Once it was decided whether differencing was required, outliers in the pre-intervention series were calculated using the log transformed data's Z-score. Z-scores of 2.5 and higher were considered outliers. The resulting outliers were forced into the pre-intervention model using dummy variables — referred to as pulses. Using such pulse variables further reduces the impact of outliers. Outliers of the post-intervention series were also calculated using Z-scores of the log transformed post-intervention series.

Autocorrelation (AC) and partial autocorrelation (PAC) plots of the transformed pre-intervention series were used to gain insight into the ARMA structure of the model. Selection of the final model was based on a comparison of AIC and BIC values of potential models, along with ARMA terms that were significant as well as within the bounds of stationarity and invertibility (see Yaffee 2000).

Using the final ARIMA structure, the complete series was then used to test the hypotheses. Dummy variables to measure the intervention effect along with control group data as well as pulse variables for outliers in the post intervention series were entered simultaneously. Effects of the intervention dummy variables are described using adjusted monthly percentage changes (coefficients of the log transformed data in the final model are transformed using the number 'e').

## 5.3 Results

### 5.3.1 Red light running at 48 camera intersections

This section contains the results from the analyses using crash data related to red light running (right angle crashes and rear end crashes) coming from 48 intersections in the city of Winnipeg where photo enforcement cameras are used. Note that crashes that could not have resulted from red light running such as crashes where the driver was reversing or parked are not included in these analyses.

**Right angle crashes at 48 camera intersections.** Figure 5-1 shows the number of right angle crashes at all 48 intersections in Winnipeg where photo enforcement cameras are used for the period of January 1994 through December 2008.

As can be seen in this figure, there is a sudden downward shift in the number of right angle crashes around the year 2003, which is the year when the photo enforcement cameras were gradually installed. It appears that the average number of right angle crashes before this shift is higher than the average number of crashes after this shift. It is also clear from this figure that there are several outliers and a few of them are extremely large. The figure further suggests that the variance of this crash series changes over time, with less variability after the intervention (the spikes before the intervention are larger than after the intervention).

To mitigate the effect of these outliers as well as the changing variance over time, raw crash numbers have been log-transformed (using the natural log transformation) and further analyses have been conducted on these transformed data. Also, to further decrease the impact of extreme outliers (those whose standardized value is still greater than 2.5 after log-transforming them), dummy variables have been created to model the outliers before determining the underlying ARIMA structure (these dummy variables are called 'pulse' in the models). Finally, robust standard errors have been used when modeling the data, which are more robust to model-misspecification (see StataCorp. 2010).

Figure 5-1: Number of right angle crashes in Winnipeg at 48 intersections with cameras from January 1994 through December 2008

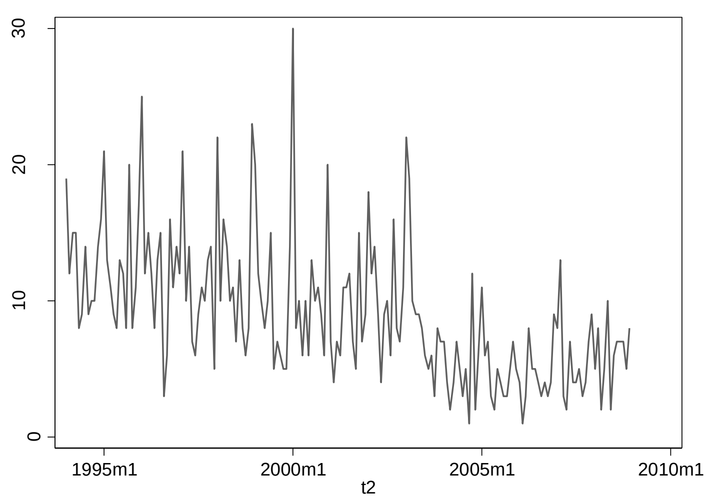


Table 5-1 has been created to better illustrate the gradual implementation of cameras and their impact. It warrants mentioning that the cameras were installed at four distinct periods in time. The first 12 cameras were installed in January 2003; the second set of 12 cameras was installed in August of 2003; the third set in July/August 2004; and, finally, the last set of 12 cameras was installed in July/August 2005. Four dummy variables have been created to indicate when each set of cameras was installed. Each observation is assigned a value 0 or 1 for this dummy variable; 0 for all observations before installation of a particular set of cameras and 1 for all observations after installation of this particular set of observations (for the third and the fourth set July 2004 and July 2005 respectively are used as the intervention month, rather than August — note that models with six dummy variables have been analyzed as well to distinguish between the installation of cameras in July versus August of 2004 and 2005 but the use of such consecutive dummies creates multicollinearity problems and does not allow to properly measure the intervention effect of interest).

This table reveals that the monthly average of crashes after installation of each set of cameras is lower than before installation. It appears that the strongest effect is associated with the installation of the second set of cameras (11.27 minus 5.26), although the differences between the before/after effects are not great.

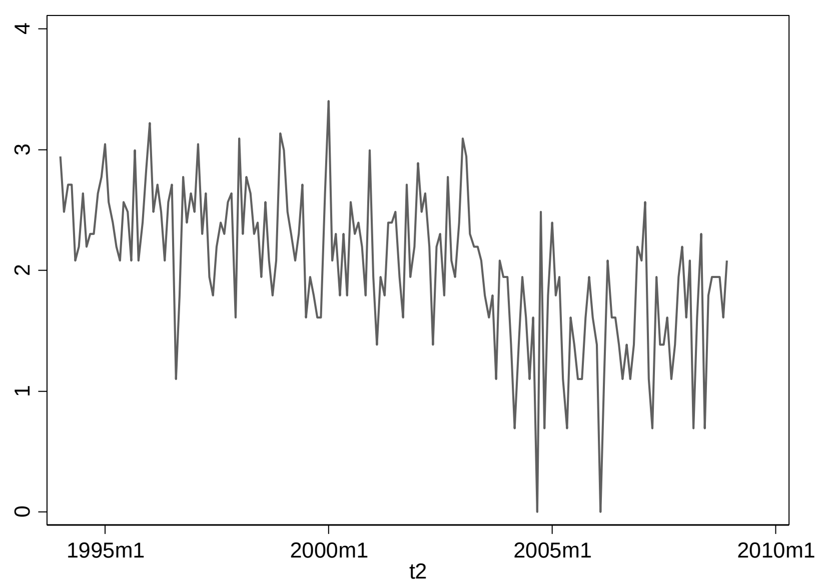
Table 5-1: Monthly average of right angle crashes and standard deviation before and after installation of cameras at 48 intersections with cameras

| Time period | # of observations (in months) | Mean of right angle crashes | Std. Dev. |
|---|---|---|---|
| *First set of 12 cameras* | | | |
| Jan. 1994 - Dec. 2002 (before) | 108 | 11.23 | 4.87 |
| Jan. 2003 - Dec. 2008 (after) | 72 | 5.90 | 3.61 |
| *Second set of 12 cameras* | | | |
| Jan. 1994 - Jul. 2003 (before) | 115 | 11.27 | 4.92 |
| Aug. 2003 - Dec. 2008 (after) | 65 | 5.26 | 2.58 |
| *Third set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2004 (before) | 126 | 10.75 | 5.03 |
| Jul. 2004 - Dec. 2008 (after) | 54 | 5.26 | 2.71 |
| *Fourth set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2005 (before) | 138 | 10.27 | 5.14 |
| Jul. 2005 - Dec. 2008 (after) | 42 | 5.26 | 2.51 |

The final time series model was based on pre-intervention data only (i.e., from January 1994 through December 2002), as suggested by McCleary and Hay (1980). This is justified because the intervention effect (i.e., the effect due to the use of the cameras) may obscure the actual underlying ARIMA structure, which would lead to model misspecification. Given that we have a long series of data (15 years in total) the pre-intervention series is sufficiently long (9 years) to properly model the data.

Figure 5-2 shows the log of the number of right angle crashes at all 48 intersections in Winnipeg where photo enforcement cameras are used for the period of January 1994 through December 2008. As can be seen, there is no apparent strong up- or downward trend in the pre-intervention series (January 1994 through December 2002), which suggests the data do not have to be differenced locally before analyzing them. This was confirmed with a formal test of a linear trend in the final pre-intervention model (-0.001; p=0.850).

Figure 5-2: Log of the number of right angle crashes in Winnipeg at 48 intersections with cameras from January 1994 through December 2008




Also, as can be seen in the correlogram (see Table 5-2), there is no strong seasonal variation suggesting seasonal differencing is not required either.

The autocorrelation and partial autocorrelation of the pre-intervention series can also be seen in Figures 5-3 and 5-4. These figures suggest the underlying process is likely autoregressive with no moving average component.

Table 5-2: Autocorrelation and partial autocorrelation of the pre-intervention log transformed number of right angle crashes at 48 camera intersections

```
                                                -1       0       1 -1       0       1
 LAG       AC        PAC        Q      Prob>Q  [Autocorrelation]  [Partial Autocor]
-------------------------------------------------------------------------------------
1        0.1220   0.1220   1.6528  0.1986           |                  |
2       -0.0062  -0.0213    1.657  0.4367           |                  |
3        0.0299   0.0357   1.7581  0.6241           |                  |
4       -0.1276  -0.1390   3.6175  0.4602          -|                 -|
5       -0.0533  -0.0202   3.9456  0.5573           |                  |
6        0.0159   0.0210   3.9749  0.6801           |                  |
7        0.0233   0.0285   4.0389  0.7753           |                  |
8       -0.0781  -0.1086   4.7627  0.7826           |                  |
9        0.1032   0.1343   6.0418  0.7357           |                  |-
10       0.0876   0.0619   6.9718  0.7281           |                  |
11       0.1316   0.1522   9.0934  0.6133           |-                 |-
12       0.1714   0.1433   12.728  0.3891           |-                 |-
13       0.1315   0.1543   14.892  0.3142           |-                 |-
14       0.0082   0.0121     14.9  0.3850           |                  |
15       0.0920   0.1886   15.981  0.3833           |                  |-
16       0.0987   0.1253   17.238  0.3703           |                  |-
17      -0.0092   0.0708   17.249  0.4376           |                  |
18       0.0100   0.0544   17.263  0.5051           |                  |
19      -0.0294   0.0095   17.378  0.5643           |                  |
20      -0.1468  -0.1648   20.286  0.4402          -|                 -|
21       0.0551   0.1534   20.701  0.4774           |                  |-
22       0.0603  -0.0882   21.203  0.5082           |                  |
23       0.1038   0.1376   22.709  0.4778           |                  |-
24       0.1733   0.1595   26.959  0.3064           |-                 |-
25       0.0747   0.0382   27.757  0.3192           |                  |
26       0.1633   0.2728   31.622  0.2059           |-                 |--
27      -0.0454  -0.0505   31.924  0.2349           |                  |
28      -0.0086  -0.0062   31.935  0.2772           |                  |
29      -0.1405  -0.0970   34.904  0.2077          -|                  |
30      -0.0089   0.1277   34.916  0.2457           |                  |-
31      -0.0978  -0.1331   36.392  0.2320           |                 -|
32      -0.0581  -0.0401   36.919  0.2520           |                  |
33       0.0251  -0.0525   37.018  0.2887           |                  |
34      -0.0247  -0.0974   37.116  0.3273           |                  |
35       0.1607   0.1759   41.321  0.2139           |-                 |-
36       0.0682   0.0502   42.089  0.2241           |                  |
37       0.1310   0.1012   44.959  0.1730           |-                 |
38       0.0946   0.2746   46.477  0.1627           |                  |--
39       0.0327   0.0080    46.66  0.1865           |                  |
40      -0.1334  -0.0601    49.77  0.1384          -|                  |
```

Figure 5-3: Autocorrelation of the pre-intervention log-transformed right angle crashes series

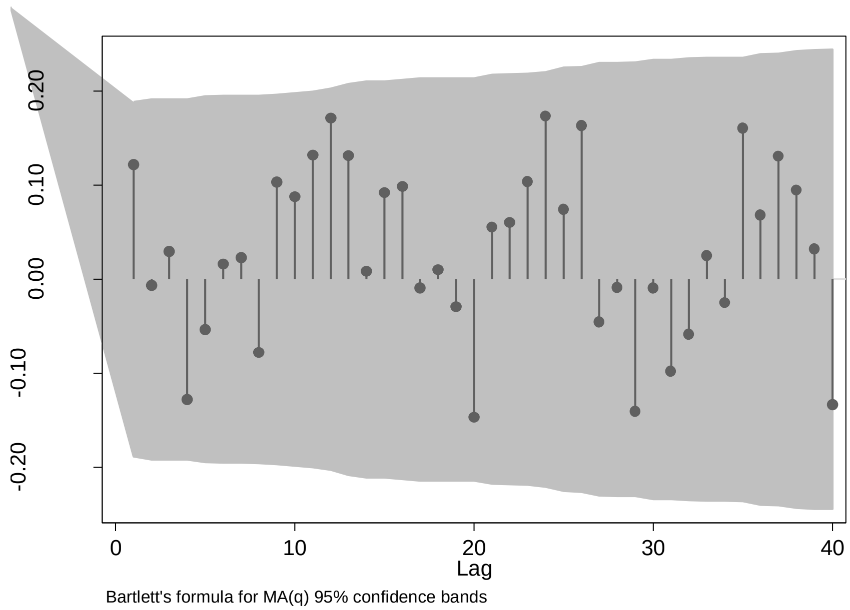
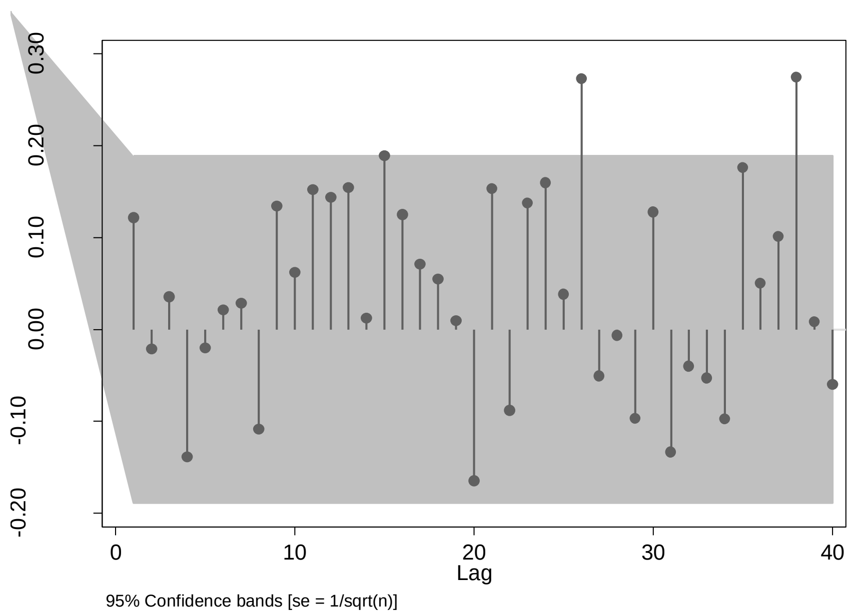



Figure 5-4: Partial autocorrelation of the pre-intervention log-transformed right angle crashes series




Several models that were considered viable based on the information from the autocorrelation and partial autocorrelation plots were compared to one another using AIC and BIC as well as the significant values of the ARIMA structure. The following model was found with the lowest AIC and BIC values (155.67 and 166.40 respectively), as well as significant ARMA terms that are within the bounds of stationarity and invertibility (see Yaffee 2000). Not surprisingly, the ARMA structure is autoregressive with no moving average components (note that one pulse variable was used to model outliers in the pre-intervention series).

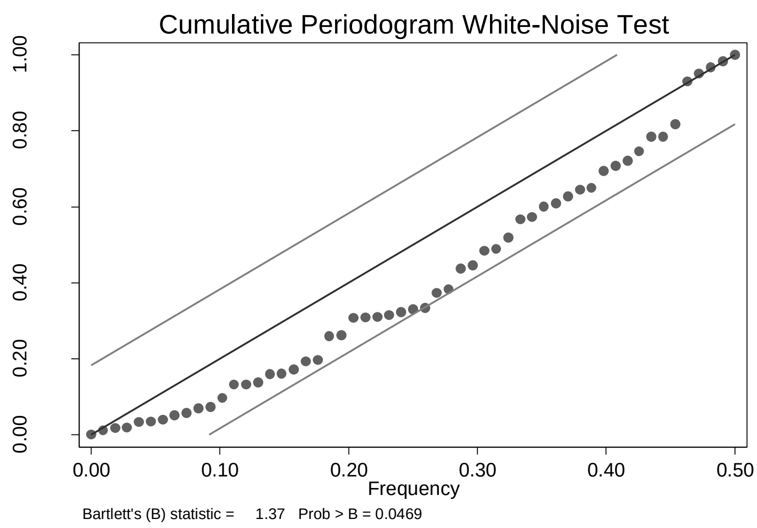
```
ARIMA regression

      Sample:  1994m1 - 2002m12                         Number of obs      =       108
                                                        Wald chi2(3)       = 138979.00
      Log pseudolikelihood = -73.83438                  Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
                   |              Semirobust
      lnrightan~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrightan~48 |
            pulse1 |  -1.028738   .3157912    -3.26   0.001    -1.647677   -.4097982
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .4912461   .0774879     6.34   0.000     .3393727    .6431195
              L12. |   .5053368   .0782316     6.46   0.000     .3520057    .6586678
      -------------+----------------------------------------------------------------
            /sigma |    .459926    .034438    13.36   0.000     .3924286    .5274233
      ------------------------------------------------------------------------------
```

A white noise test of the residuals of this final model confirms the residuals are indeed distributed according to a white noise pattern. While strictly speaking Bartlett's statistic rejects the Null hypothesis of white noise (1.37; p=0.047), it is clear that all the dots in the figure below, except one are within the confidence bounds. Also, Portmanteau's test does not reject the Null hypothesis of white noise (48.31; p=0.17).

Figure 5-5: Cumulative periodogram white noise test and Bartlett's statistic of the residuals of the final pre-intervention model




The following graphs also show that the residuals of this model are normally distributed, again an indication that the assumptions of the model are satisfied.

Figure 5-6: Standardized normal probability plot of the residuals of the final pre-intervention model

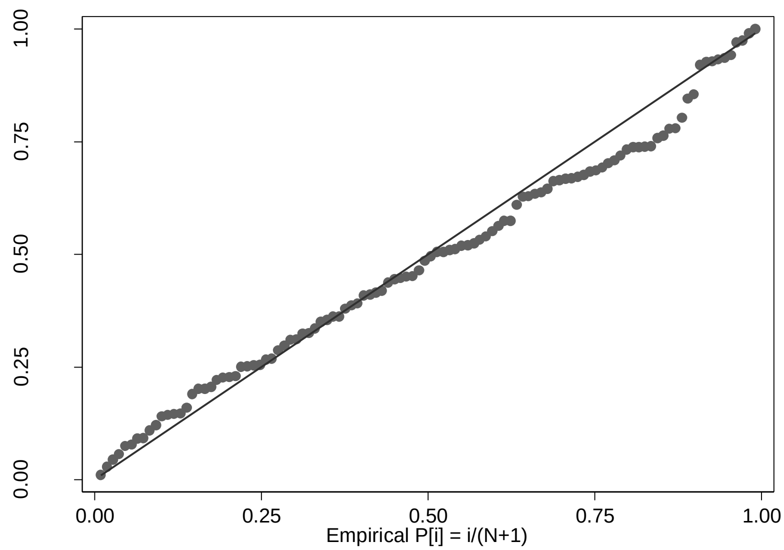
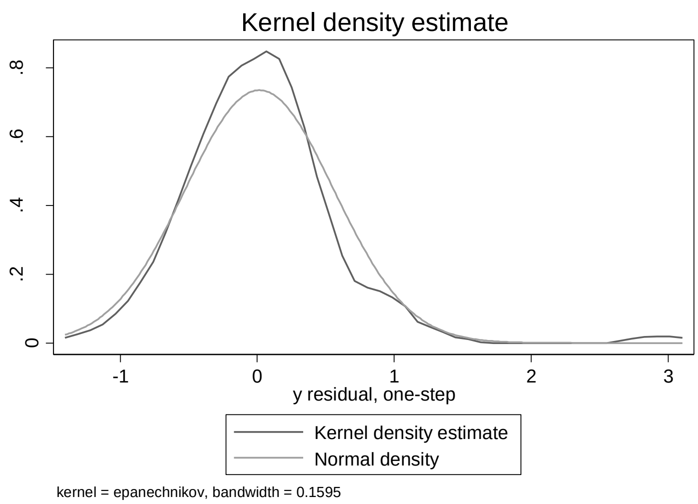
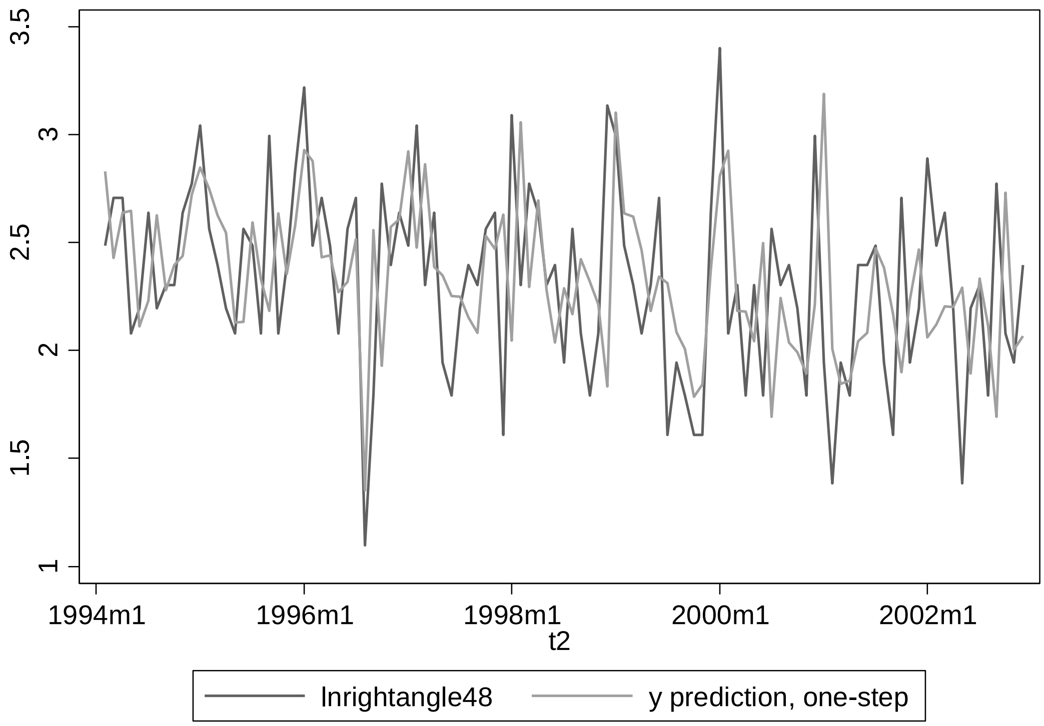



Figure 5-7: Normal density plot of the residuals of the final pre-intervention model




Finally, Figure 5-8 shows how the final model fits with the actual data of the pre-intervention series. Based on these one-step-ahead predictions, the model seems to fit the data well.

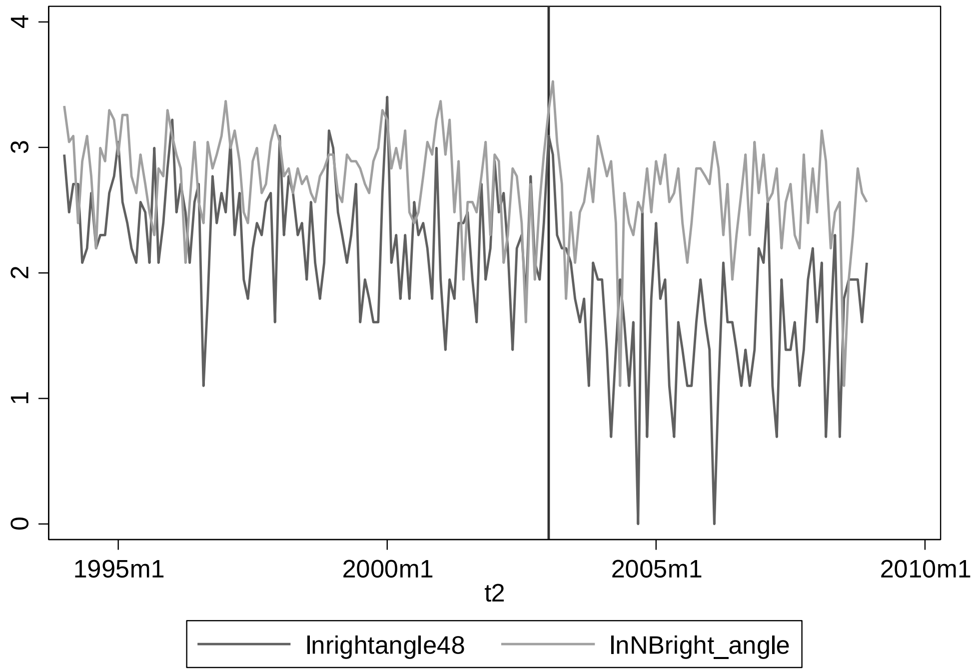
Figure 5-8: log-transformed number of right angle crashes and one-step-ahead predictions according to final model for 48 intersections with cameras, pre-intervention




Once the final model was obtained based on the pre-intervention series, hypotheses regarding the impact of the introduction of cameras were tested. Four dummy variables representing the use of four sets of cameras along with data from a control group were simultaneously introduced in the final model. Data from the province of New Brunswick are used as a control group. The same selection criteria for crashes are applied as those used with the data from Winnipeg (i.e., right angle crashes excluding crashes involving vehicles reversing or in parked position).

Figure 5-9 contains both series of crashes, i.e., the experimental group with right angle crashes from Winnipeg and the control group with right angle crashes from New Brunswick. The vertical line indicates the time when the first set of cameras was installed in Winnipeg, which coincides with the decrease in right angle crashes. Clearly the intervention in Winnipeg had an effect on crashes that did not occur in the control group.

Figure 5-9: log-transformed number of right angle crashes in the experimental group (Winnipeg, lnrightangle48) and the control group (New Brunswick, lnNBright_angle)




As can be seen in the model with the dummy variables and control group data, the installation of the first set of cameras was associated with a non-significant increase in right angle crashes of 12.75% ($\omega$=0.120, p=0.267; if $\omega$ represents the coefficient of the intervention effect then the adjusted monthly percentage change in the post-intervention series relative to the pre-intervention series can be calculated using $(100 \text{ x } (e^{\omega} - 1))$, followed by a highly significant decrease of 46.10% ($\omega$=-0.618; p=0.003); a non-significant decrease of 10.68% ($\omega$=-0.113; p=0.691); and a non-significant increase of 10.96% ($\omega$=0.104; p=0.598).

Note that the AR terms are no longer significant in this model. When looking at the same model excluding the control group data, the AR terms are significant again and the same overall conclusions can be drawn from this model with respect to the dummy variables, i.e., a strong significant decrease in right angle crashes associated with the installation of the second set of cameras.

```
ARIMA regression with control group

      Sample:  1994m1 - 2008m12                       Number of obs      =       180
                                                      Wald chi2(11)      = 445675.44
      Log pseudolikelihood = -124.8815                Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
                   |                 Semirobust
      lnrightan~48 |      Coef.    Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrightan~48 |
            pulse1 |  -.8704473    .0489997   -17.76   0.000     -.966485   -.7744097
            pulse2 |   .3321097    .1065066     3.12   0.002     .1233606    .5408588
            pulse3 |  -1.546411    .2395843    -6.45   0.000    -2.015987   -1.076834
            pulse4 |  -1.823008     .239651    -7.61   0.000    -2.292716   -1.353301
      lnNBright_~e |    .820086    .0150004    54.67   0.000     .7906858    .8494863
            dummy1 |   .1197811    .1078163     1.11   0.267     -.091535    .3310973
            dummy2 |  -.6179981    .2107294    -2.93   0.003     -1.03102    -.204976
            dummy3 |  -.1131996    .2847636    -0.40   0.691     -.671326    .4449268
            dummy4 |   .1039477    .1971603     0.53   0.598    -.2824793    .4903746
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .0260315    .0872546     0.30   0.765    -.1449843    .1970473
              L12. |  -.1240786    .0856033    -1.45   0.147     -.291858    .0437007
      -------------+----------------------------------------------------------------
            /sigma |   .4839763     .028215    17.15   0.000     .4286759    .5392767
      ------------------------------------------------------------------------------

ARIMA regression without control group

      Sample:  1994m1 - 2008m12                       Number of obs      =       180
                                                      Wald chi2(10)      =  53980.64
      Log pseudolikelihood =  -132.685                Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
                   |                 Semirobust
      lnrightan~48 |      Coef.    Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrightan~48 |
            pulse1 |  -1.029004    .3140611    -3.28   0.001    -1.644553   -.4134558
            pulse2 |   .2454519    .1800023     1.36   0.173    -.1073462      .59825
            pulse3 |  -1.969034    .4287903    -4.59   0.000    -2.809447    -1.12862
            pulse4 |  -1.609196    .3656249    -4.40   0.000    -2.325807   -.8925841
            dummy1 |   .1484111    .2260045     0.66   0.511    -.2945495    .5913717
            dummy2 |  -.7005251    .2807593    -2.50   0.013    -1.250803    -.150247
            dummy3 |   .0270361    .3454565     0.08   0.938    -.6500462    .7041185
            dummy4 |  -.0470172    .2407622    -0.20   0.845    -.5189023     .424868
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .4921344    .0709957     6.93   0.000     .3529853    .6312835
              L12. |   .5032438     .071752     7.01   0.000     .3626124    .6438752
      -------------+----------------------------------------------------------------
            /sigma |   .4937695    .0269322    18.33   0.000     .4409832    .5465557
      ------------------------------------------------------------------------------
```

In conclusion, a non-significant increase in right angle crashes of 13% was found soon after the introduction of the first set of 12 cameras. A highly significant, strong decrease of 46% was associated with the introduction of the second set of cameras. This was followed by a non-significant decrease of 11%. These decreases were followed by a non-significant increase of 11%. The effect can clearly be seen on the graph of monthly crashes in the form of a downward shift and this shift is not at all apparent for the control group (see Figure 5-9). The initial small and non-significant increase might suggest a delayed intervention effect, while the small and non-significant increase associated with the last set of cameras might be the result of regression to the mean.

**Rear end crashes at 48 camera intersections.** As can be seen in Figure 5-10, comparable to the pattern of right angle crashes, there appear to be several outliers in the series of rear end crashes. Also, the variance changes over time. For these reasons, the analyses will be conducted using log transformed numbers, rather than raw crash numbers. The figure also suggests that the average number of rear end crashes is higher after the intervention in 2003, although this average appears to be decreasing again at the end of the series.

Table 5-3 contains comparable information as Table 5-1 but this time for rear end crashes rather than right angle crashes. Consistent with the figure, the monthly average of rear end crashes is higher after installation of each set of cameras. The differences between the means before and after installation of the cameras (four differences in total) are close to one another and are smaller for later interventions.

Figure 5-10: Number of rear end crashes in Winnipeg at 48 intersections with cameras from January 1994 through December 2008

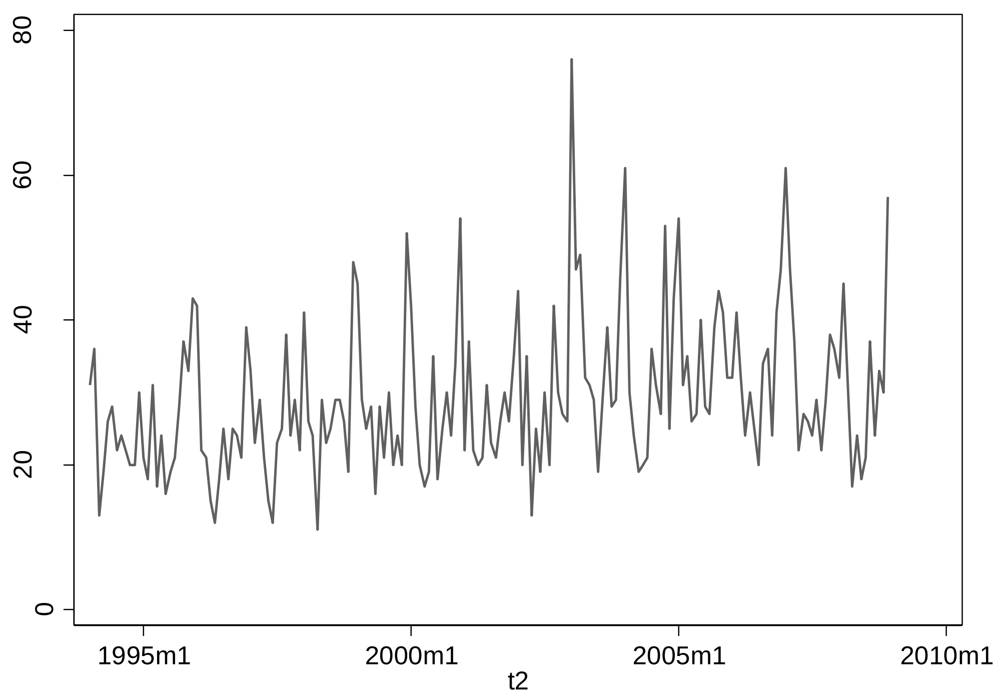


Table 5-3: Monthly average of rear end crashes and standard deviation before and after installation of cameras at 48 intersections with cameras

| Time period | # of observations (in months) | Mean of rear end crashes | Std. Dev. |
|---|---|---|---|
| *First set of 12 cameras* | | | |
| Jan. 1994 - Dec. 2002 (before) | 108 | 26.24 | 8.61 |
| Jan. 2003 - Dec. 2008 (after) | 72 | 33.64 | 11.48 |
| *Second set of 12 cameras* | | | |
| Jan. 1994 - Jul. 2003 (before) | 115 | 27.10 | 9.99 |
| Aug. 2003 - Dec. 2008 (after) | 65 | 32.91 | 10.36 |
| *Third set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2004 (before) | 126 | 27.49 | 10.27 |
| Jul. 2004 - Dec. 2008 (after) | 54 | 33.19 | 9.93 |
| *Fourth set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2005 (before) | 138 | 28.20 | 10.48 |
| Jul. 2005 - Dec. 2008 (after) | 42 | 32.48 | 9.90 |

When looking at the log transformed crash numbers, an intervention effect is apparent, albeit not as strong as with right angle crashes (see Figure 5-11). While Figures 5-1 and 5-2 show there was a sudden downward shift in right angle crashes associated with the introduction of cameras, this figure (and Figure 5-10) reveals there might have been an increase in rear end crashes associated with the introduction of cameras but the shift is not as pronounced as with right angle crashes.

The pre-intervention series (January 1994 through December 2002) in Figure 5-11 is flat, suggesting local differencing is not necessary. This was confirmed with a formal test (0.001; p=0.535). Also, as can be seen in the correlogram (see Table 5-4), there is some seasonal variation, suggesting seasonal differencing is required.

Figure 5-11: Log of the number of rear end crashes in Winnipeg at 48 intersections with cameras from January 1994 through December 2008

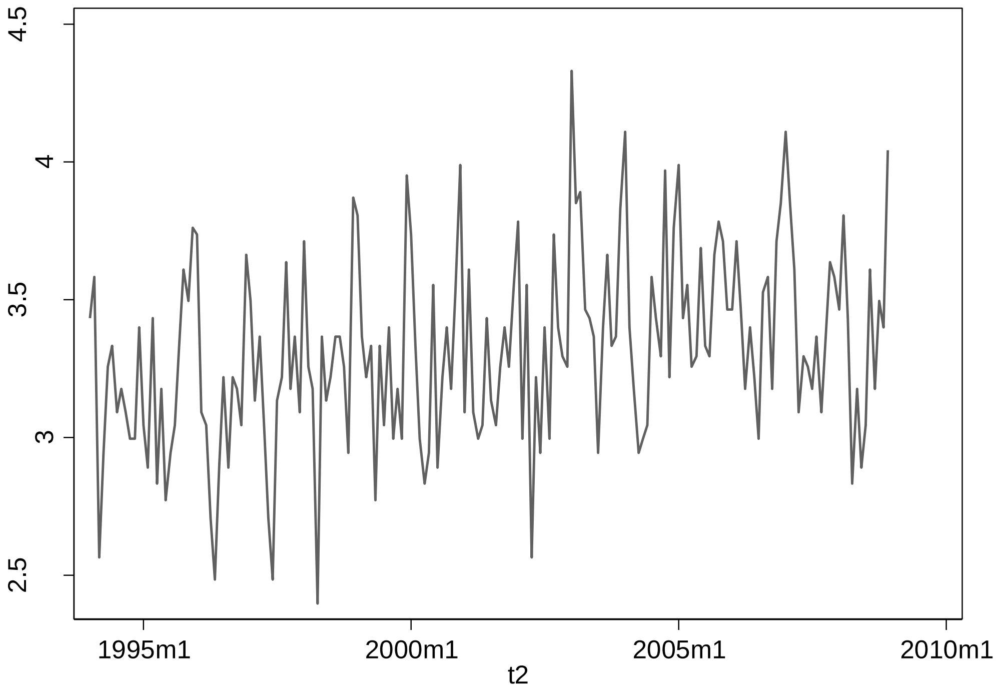


Table 5-4: Autocorrelation and partial autocorrelation of the pre-intervention log transformed number of rear end crashes at 48 camera intersections

```
                                          -1       0       1 -1       0       1
LAG       AC       PAC      Q     Prob>Q  [Autocorrelation]  [Partial Autocor]
-------------------------------------------------------------------------------
1       0.1637   0.1637   2.9746  0.0846          |-                 |-
2       0.1351   0.1125   5.0203  0.0813          |-                 |
3      -0.1317  -0.1812   6.9837  0.0724         -|                 -|
4      -0.1083  -0.0874   8.3231  0.0804          |                  |
5      -0.2878  -0.2335   17.874  0.0031        --|                 -|
6      -0.0343   0.0608   18.011  0.0062          |                  |
7      -0.2295  -0.2239   24.206  0.0010         -|                 -|
8      -0.1306  -0.1825   26.232  0.0010         -|                 -|
9      -0.0473  -0.0084     26.5  0.0017          |                  |
10      0.1410   0.0934   28.912  0.0013          |-                 |
11      0.2533   0.2076   36.772  0.0001          |--                |-
12      0.3020   0.1271   48.059  0.0000          |--                |-
13      0.2528   0.2016   56.049  0.0000          |--                |-
14      0.0082  -0.0675   56.057  0.0000          |                  |
15      0.0141   0.1220   56.083  0.0000          |                  |
16     -0.1234  -0.0106   58.048  0.0000          |                  |
17     -0.0862   0.0609   59.018  0.0000          |                  |
18     -0.1652  -0.0061   62.619  0.0000         -|                  |
19     -0.1412  -0.0517   65.282  0.0000         -|                  |
20     -0.1912  -0.0234   70.216  0.0000         -|                  |
21     -0.0130  -0.0274   70.239  0.0000          |                  |
22      0.0836   0.0737   71.204  0.0000          |                  |
23      0.3026   0.1729   84.006  0.0000          |--                |-
24      0.3169   0.2414   98.213  0.0000          |--                |-
25      0.2018   0.1296   104.04  0.0000          |-                 |-
26     -0.0307  -0.0645   104.18  0.0000          |                  |
27     -0.0275   0.0322   104.29  0.0000          |                  |
28     -0.1204  -0.0482   106.44  0.0000          |                  |
29     -0.0563   0.0258   106.92  0.0000          |                  |
30     -0.1466  -0.1217   110.19  0.0000         -|                  |
31     -0.1450  -0.0157   113.44  0.0000         -|                  |
32     -0.1815  -0.1112   118.59  0.0000         -|                  |
33      0.0864   0.1914   119.77  0.0000          |                  |-
34      0.0095  -0.2043   119.78  0.0000          |                 -|
35      0.1785  -0.1468   124.97  0.0000          |-                -|
36      0.1421   0.0506    128.3  0.0000          |-                 |
37      0.1757   0.0641   133.47  0.0000          |-                 |
38      0.0468   0.2829   133.84  0.0000          |                  |--
39      0.0909   0.2084   135.26  0.0000          |                  |-
40     -0.1737  -0.2443   140.53  0.0000         -|                 -|
```

As with right angle crashes the final model will be based on the pre-intervention series only for reasons explained previously. The autocorrelation and partial autocorrelation of the log transformed, seasonally differenced pre-intervention series can be seen separately in Figures 5-12 and 5-13. Most values are not that strong, with the exception of the value associated with the twelfth lag.

Figure 5-12: Autocorrelation of the pre-intervention log-transformed and seasonally differenced rear end crash series

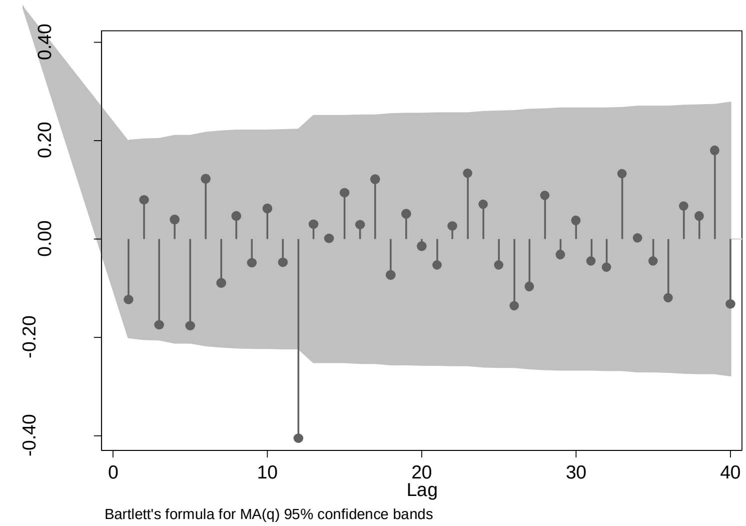
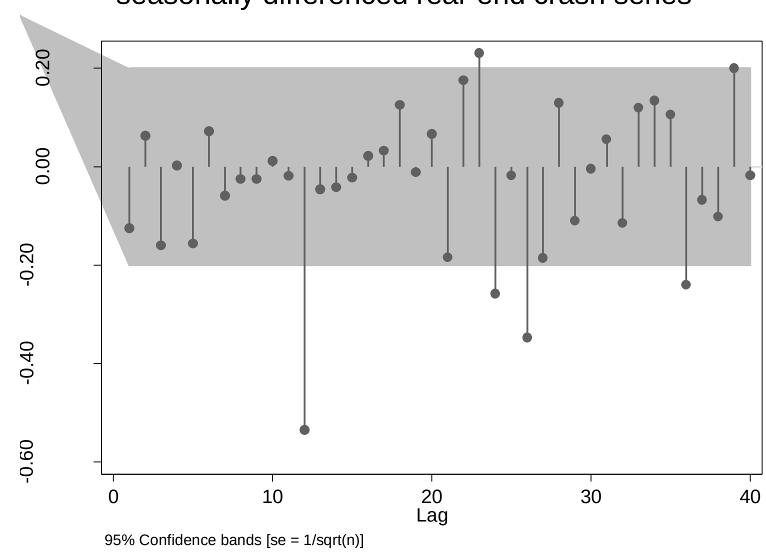



Figure 5-13: Partial autocorrelation of the pre-intervention log-transformed and seasonally differenced rear end crash series




Several models that were considered viable based on the information from the autocorrelation and partial autocorrelation plots were compared to one another using AIC and BIC as well as the significant values of the ARIMA structure. The following model was found with the lowest AIC and BIC values (60.44 and 70.70 respectively), as well as significant ARMA terms that are within the bounds of stationarity and invertibility.

It warrants mentioning that the AR term associated with the first lag is not significant. For this reason, results were compared with a model that only contains the seasonal AR term and they were consistent across both models. Given that purely seasonal models are not that common and that these data come from the same population as with the right angle crashes model, results from the model with both AR terms are presented here.

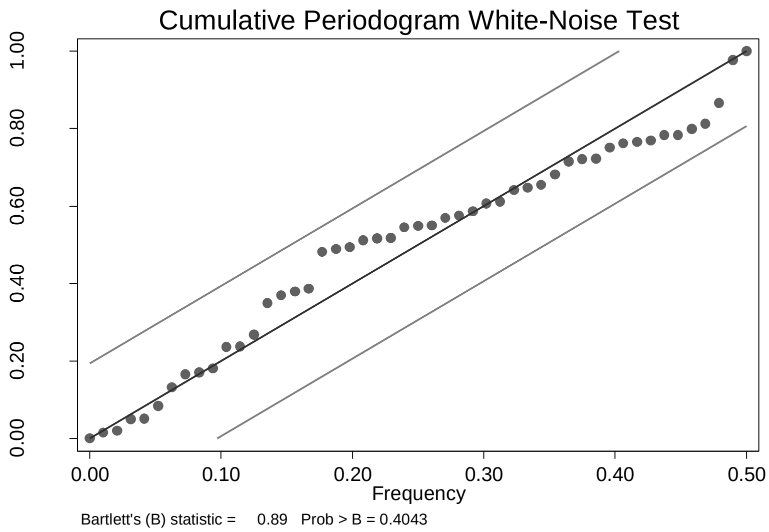
```
ARIMA regression

      Sample:  1995m1 - 2002m12                         Number of obs      =        96
                                                        Wald chi2(3)       =     51.88
      Log pseudolikelihood = -26.22044                  Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |              Semirobust
       lnrearend48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrearend48  |
            pulse1 |
              S12. |  -.4608646   .2031701    -2.27   0.023    -.8590708   -.0626584
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |  -.1022343   .1014298    -1.01   0.313     -.301033    .0965644
              L12. |  -.4851318   .1009656    -4.80   0.000    -.6830208   -.2872428
      -------------+----------------------------------------------------------------
            /sigma |    .312575   .0213674    14.63   0.000     .2706956    .3544544
      ------------------------------------------------------------------------------
```

A white noise test of the residuals of this final model confirms the residuals are indeed distributed according to a white noise pattern. According to Bartlett's statistic the Null hypothesis of white noise can not be rejected (0.89; p=0.40) and the dots in the figure below are all within the confidence bounds. Also, Portmanteau's test does not reject the Null hypothesis of white noise (51.84; p=0.10).

Figure 5-14: Cumulative periodogram white noise test and Bartlett's statistic of the residuals of the final pre-intervention model



The following graphs also show that the residuals of this model are normally distributed.

Figure 5-15: Standardized normal probability plot of the residuals of the final pre-intervention model

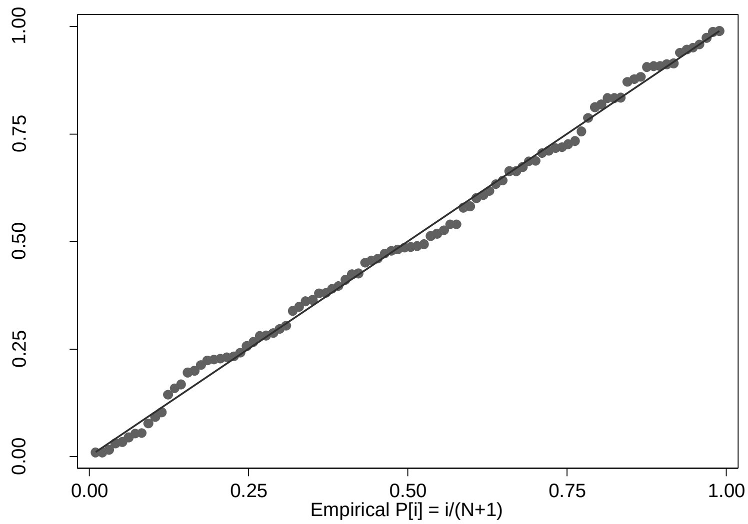
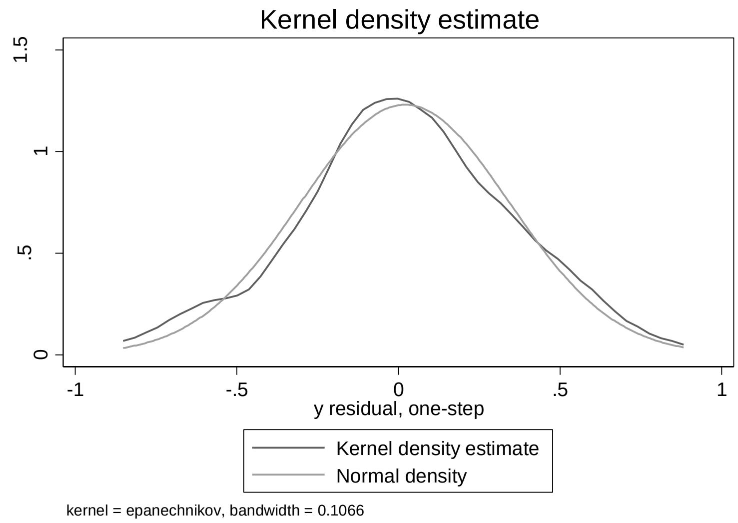
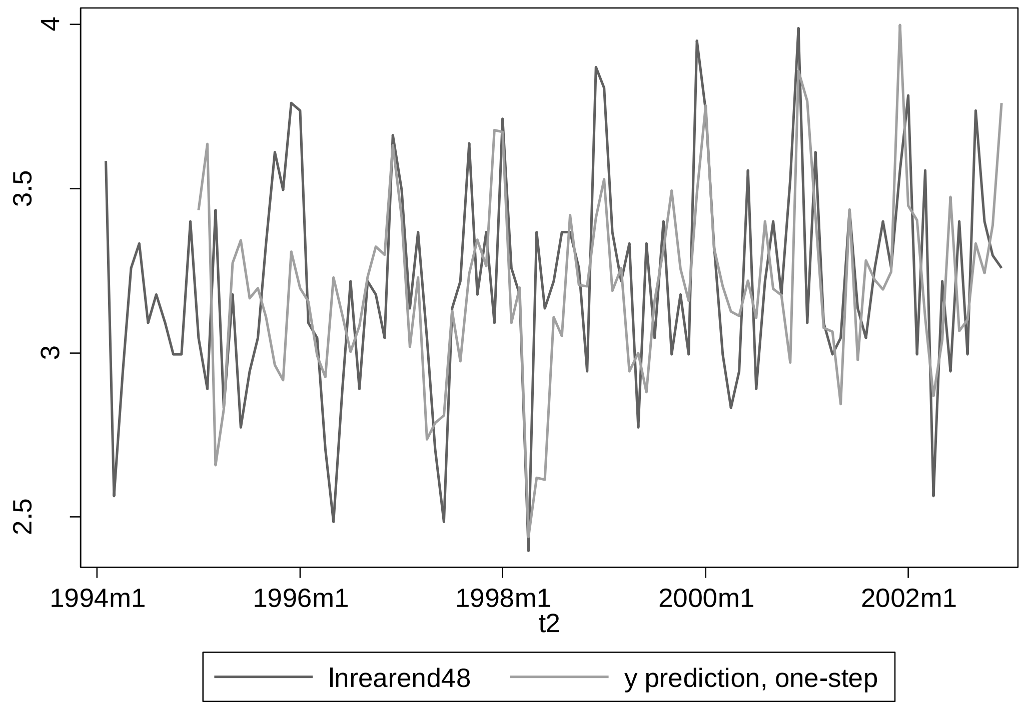



Figure 5-16: Normal density plot of the residuals of the final pre-intervention model




Finally, Figure 5-17 shows how the final model fits with the actual data of the pre-intervention series. Based on these one-step-ahead predictions, the model seems to fit the data well.

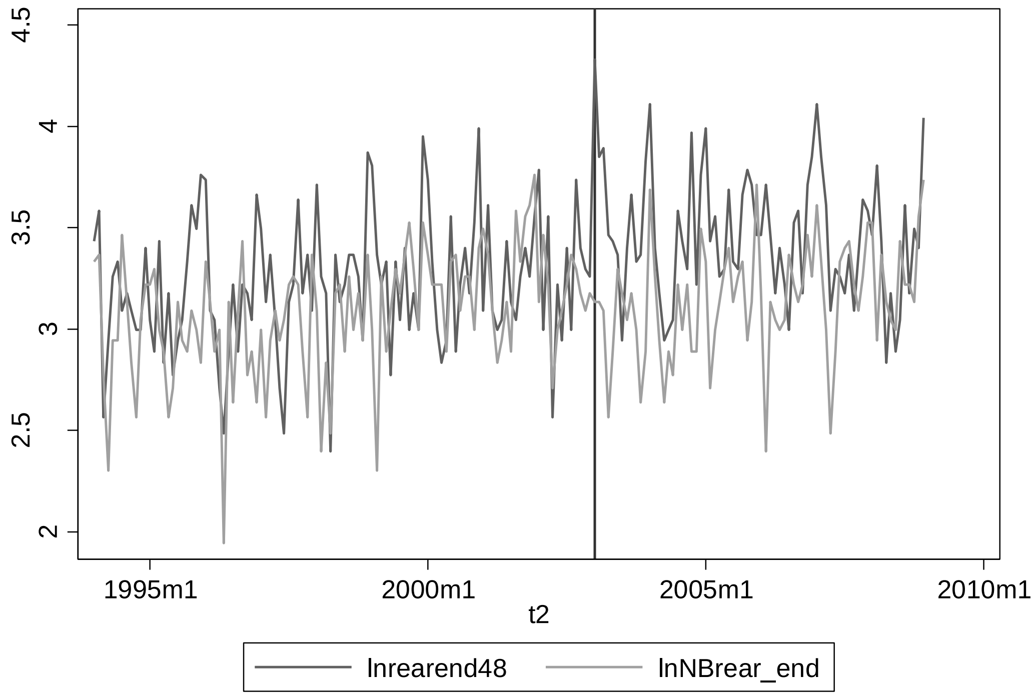
Figure 5-17: log-transformed number of rear end crashes and one-step-ahead predictions according to final model for 48 intersections with cameras, pre-intervention




Again, once the final model was obtained, hypotheses regarding the impact of the introduction of cameras were tested. The four dummy variables representing the installation of four sets of cameras along with control group data from New Brunswick were simultaneously introduced in the final model.

Figure 5-18 contains both series of crashes, i.e., the experimental group with rear end crashes from Winnipeg and the control group with rear end crashes from New Brunswick. The vertical line indicates the time when the first set of cameras was installed in Winnipeg.

Figure 5-18: log-transformed number of rear end crashes in the experimental group (Winnipeg, lnrearend48) and the control group (New Brunswick, lnNBrear_end)




It warrants mentioning that all the independent variables in the model below (pulses, dummies and control group data) have been seasonally transformed to make them correspond to the dependent variable that was seasonally transformed, as suggested by Van den Bossche et al. (2004) and Pankratz (1991).

As can be seen in the model with the dummy variables and control group data, there was a significant 42.33% increase in rear end crashes when the first set of cameras was installed (0.353; p=0.004). This was followed by a significant decrease (at the 10% level rather than then the 5% level; -0.209; p=0.085) in rear end crashes of 18.86%, associated with the installation of the second set of cameras. The effects associated with the installation of the third and fourth set of cameras are no longer significant.

This pattern suggests drivers may initially have used their brakes more abruptly for fear of being ticketed when approaching camera intersections and this likely led to an increase in crashes. However, the data also suggest that drivers soon adjusted their behaviour to the presence of cameras and this then led to a decrease. The net effect of this increase followed by the decrease was a 15.49% increase in rear end crashes ($\omega$=0.353-0.209 — note that percent change is an asymmetrical measure so to calculate the true net effect, percent increases and decreases cannot be added up but rather the log coefficients have to be added up and the result has to be transformed using the formula $(100 \text{ x } (e^{\omega} - 1))$.

As mentioned previously, a model with only one AR term was tested as well (the AR term associated with the 12th lag). The results were consistent with the results from the model with two AR terms, although the decrease associated with the installation of the second set of cameras was somewhat smaller and no longer significant at the 10% level (-0.200; p=0.101).

```
ARIMA regression with control group, AR 1 12

      Sample:  1995m1 - 2008m12                       Number of obs      =       168
                                                      Wald chi2(9)       =    126.62
      Log pseudolikelihood = -35.57072                Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |              Semirobust
       lnrearend48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrearend48  |
            pulse1 |
              S12. |  -.4465395   .1908891    -2.34   0.019    -.8206753   -.0724038
                   |
            pulse2 |
              S12. |    .435957    .177408     2.46   0.014     .0882437    .7836703
                   |
      lnNBrear_end |
              S12. |   .0663833   .0873529     0.76   0.447    -.1048252    .2375918
                   |
            dummy1 |
              S12. |   .3527552   .1225909     2.88   0.004     .1124814     .593029
                   |
            dummy2 |
              S12. |  -.2092426   .1214005    -1.72   0.085    -.4471832     .028698
                   |
            dummy3 |
              S12. |   .1348485   .0912447     1.48   0.139    -.0439877    .3136847
                   |
            dummy4 |
              S12. |  -.0290076   .0803828    -0.36   0.718    -.1865549    .1285397
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |  -.0401243   .0727876    -0.55   0.581    -.1827854    .1025367
              L12. |  -.5058106   .0711401    -7.11   0.000    -.6452426   -.3663786
      -------------+----------------------------------------------------------------
            /sigma |   .2958755   .0155102    19.08   0.000      .265476     .326275
      ------------------------------------------------------------------------------
```

In conclusion, the results from this analysis do suggest there has been and increase in rear end crashes associated with the installation of the first set of cameras, but this increase was followed by a borderline significant decrease and further non-significant effects. This might be indicative of learning behaviour taking place. Other evaluations of the impact of photo enforcement have found similar results where initial increases in rear end crashes are followed by decreases when drivers become habituated to the presence of cameras and no longer brake abruptly at intersections with photo enforcement.

**5.3.2 Red light running in Winnipeg excluding 48 camera intersections**

In an effort to gauge whether there were spill-over effects in the city of Winnipeg (i.e., whether the impact of the photo enforcement program extended beyond the 48 intersections where cameras are used) the analyses were replicated in this section with data from all signalized intersections in Winnipeg, excluding the 48 camera intersections.

**Right angle crashes in Winnipeg.** As can be seen in Figure 5-19, there are some outliers in this series of crashes at signalized intersections in Winnipeg excluding the 48 camera intersections. Also, the series is rather flat with a very weak downward local trend. The clear downward shift in right angle crashes at camera intersections associated with the use of cameras that stood out in Figure 5-1 is no longer visible with the naked eye when looking at data for the other intersections in Winnipeg that do not have cameras.

Figure 5-19: Number of right angle crashes in Winnipeg, excluding 48 camera intersections from January 1994 through December 2008

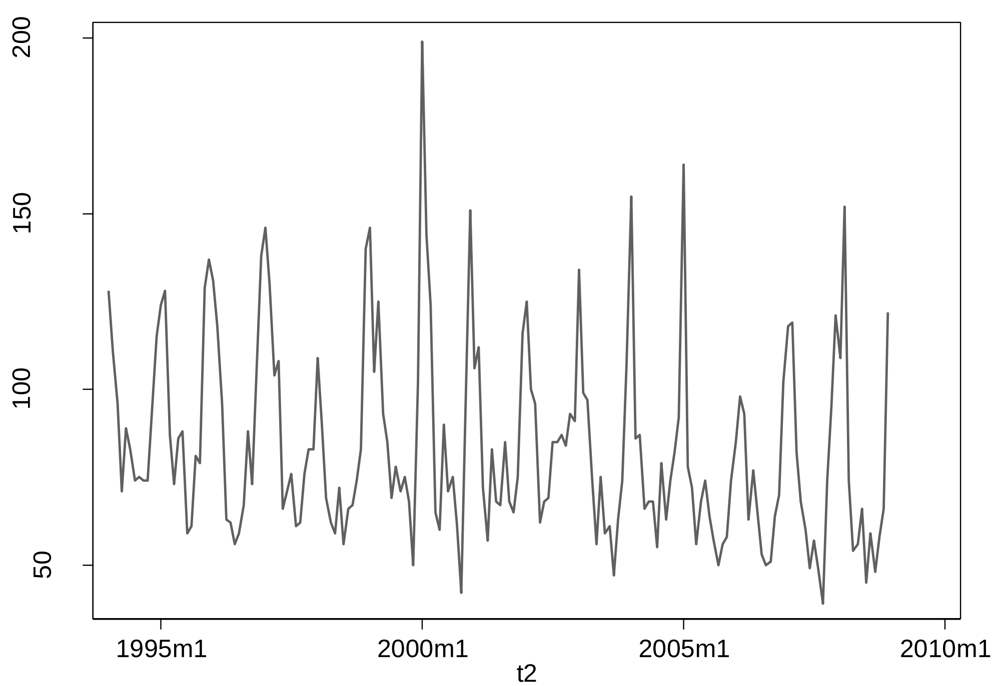


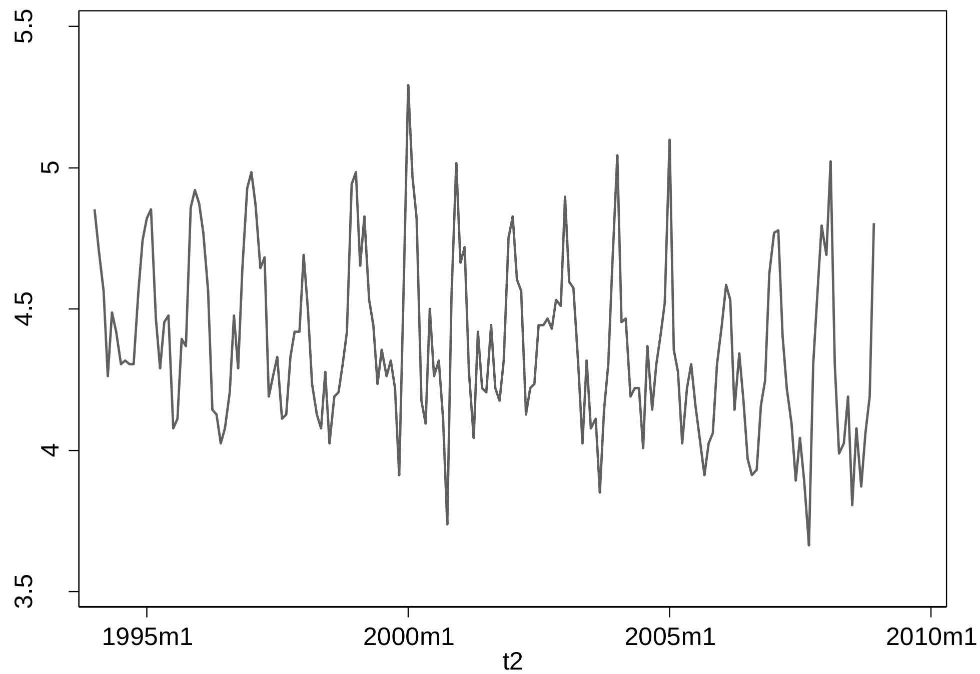
Table 5-5 contains information in line with Figure 5-19. It shows that the monthly average of right angle crashes in Winnipeg after the introduction of each set of cameras is lower than the monthly average before the introduction of cameras. However, given the pattern of Figure 5-19 with no apparent downward shift, it remains to be seen whether the analyses will reveal any significant decrease associated with the installation of cameras.

Table 5-5: Monthly average of right angle crashes and standard deviation before and after installation of cameras in Winnipeg, excluding camera intersections

| Time period | # of observations (in months) | Mean of right angle crashes | Std. Dev. |
|---|---|---|---|
| *First set of 12 cameras* | | | |
| Jan. 1994 - Dec. 2002 (before) | 108 | 88.41 | 27.25 |
| Jan. 2003 - Dec. 2008 (after) | 72 | 76.43 | 26.74 |
| *Second set of 12 cameras* | | | |
| Jan. 1994 - Jul. 2003 (before) | 115 | 88.19 | 27.15 |
| Aug. 2003 - Dec. 2008 (after) | 65 | 75.52 | 26.73 |
| *Third set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2004 (before) | 126 | 87.49 | 27.33 |
| Jul. 2004 - Dec. 2008 (after) | 54 | 74.57 | 26.33 |
| *Fourth set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2005 (before) | 138 | 86.82 | 27.42 |
| Jul. 2005 - Dec. 2008 (after) | 42 | 73.10 | 25.83 |

When looking at the log transformed crash numbers, no strong intervention effect is apparent (see Figure 5-20). Comparable to previous analyses, the final model will be based on the pre-intervention series only, using log transformed data. This pre-intervention series is flat, suggesting there is no need to difference the data locally (this was confirmed with a formal test: -0.0009; p=0.547).

Figure 5-20: Log of the number of right angle crashes in Winnipeg, excluding 48 camera intersections from January 1994 through December 2008




On the other hand, the autocorrelation and partial autocorrelation of the pre-intervention series now show a strong seasonal effect, whereas before it did not (see correlogram in Table 5-6). For this reason the data will be seasonally differenced.

The autocorrelation and partial autocorrelation of the log transformed, seasonally differenced right angle crashes in Winnipeg, excluding 48 camera intersections can be seen in Figures 5-21 and 5-22.

Table 5-6: Autocorrelation and partial autocorrelation of the pre-intervention log transformed number of right angle crashes in Winnipeg, excluding 48 camera intersections

```
                                      -1       0       1 -1       0       1
LAG       AC      PAC        Q  Prob>Q  [Autocorrelation]  [Partial Autocor]
------------------------------------------------------------------------------
1     0.5918   0.5921   38.889  0.0000         |----              |----
2     0.1773  -0.2679   42.411  0.0000         |-               --|
3    -0.0922  -0.1115   43.373  0.0000         |                  |
4    -0.3219  -0.2749    55.21  0.0000       --|                --|
5    -0.3292   0.0484   67.706  0.0000       --|                  |
6    -0.3358  -0.2661   80.843  0.0000       --|                --|
7    -0.4243  -0.3343   102.02  0.0000      ---|                --|
8    -0.3572  -0.1485   117.18  0.0000       --|                 -|
9    -0.1194   0.0709   118.89  0.0000         |                  |
10    0.1863   0.1386    123.1  0.0000         |-                 |-
11    0.4922   0.2416   152.78  0.0000         |---               |-
12    0.5516   0.0757   190.43  0.0000         |----              |
13    0.4017   0.0977   210.61  0.0000         |---               |
14    0.1435  -0.1433   213.21  0.0000         |-                -|
15   -0.1336  -0.2218   215.49  0.0000        -|                 -|
16   -0.2911  -0.1923   226.43  0.0000       --|                 -|
17   -0.3665  -0.0982   243.96  0.0000       --|                  |
18   -0.3697   0.0484      262  0.0000       --|                  |
19   -0.3096   0.0216    274.8  0.0000       --|                  |
20   -0.2243   0.0232   281.59  0.0000        -|                  |
21   -0.0791  -0.0729   282.44  0.0000         |                  |
22    0.1496  -0.1119   285.53  0.0000         |-                 |
23    0.4321   0.2398   311.63  0.0000         |---               |-
24    0.5155  -0.0283   349.22  0.0000         |----              |
25    0.3663  -0.0118   368.42  0.0000         |--                |
26    0.1542   0.0881   371.87  0.0000         |-                 |
27   -0.0935  -0.1079   373.15  0.0000         |                  |
28   -0.2409  -0.1676   381.77  0.0000        -|                 -|
29   -0.2708  -0.1383    392.8  0.0000       --|                 -|
30   -0.2848  -0.0335   405.15  0.0000       --|                  |
31   -0.2832   0.1404   417.53  0.0000       --|                  |-
32   -0.2181   0.0196   424.97  0.0000        -|                  |
33   -0.1140  -0.1373   427.02  0.0000         |                 -|
34    0.0912  -0.1060   428.36  0.0000         |                  |
35    0.3021   0.1265   443.21  0.0000         |--                |-
36    0.3911   0.1959   468.45  0.0000         |---               |-
37    0.3613   0.2113   490.29  0.0000         |--                |-
38    0.2009  -0.0799   497.14  0.0000         |-                 |
39   -0.0087  -0.1997   497.15  0.0000         |                 -|
40   -0.1070   0.2649   499.15  0.0000         |                  |--
```

Figure 5-21: Autocorrelation of pre-intervention log-transformed, seasonally differenced right angle crash series in Winnipeg, excluding 48 camera intersections

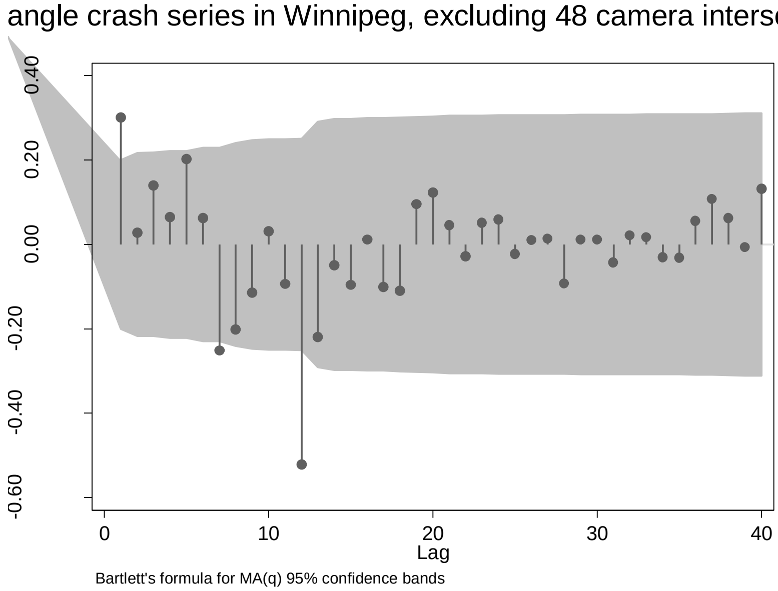
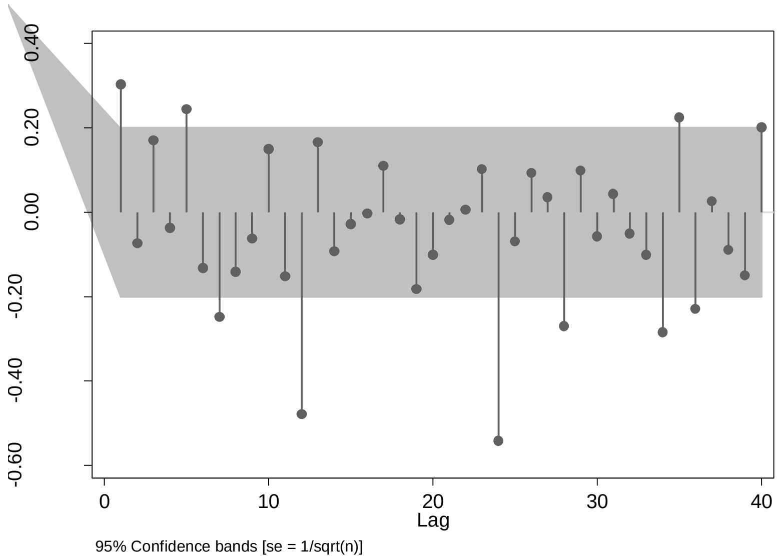


Figure 5-22: Partial autocorrelation of pre-intervention log-transformed, seasonally differenced right angle crash series in Winnipeg, excluding 48 camera intersections




Model selection was based on the same approach adopted previously. The following model was found with the lowest AIC and BIC values (-18.84 and -8.58 respectively), as well as significant ARMA terms that are within the bounds of stationarity and invertibility. As before, the ARMA structure is autoregressive with no moving average components.

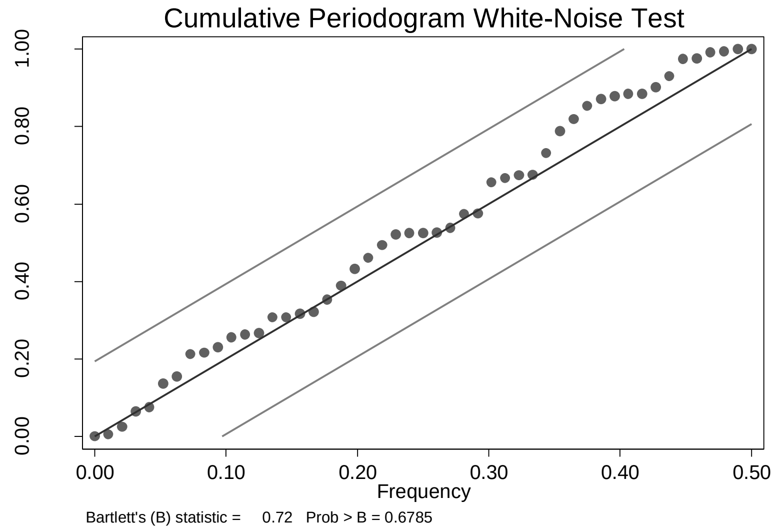
```
ARIMA regression

      Sample:  1995m1 - 2002m12                      Number of obs      =        96
                                                     Wald chi2(3)       =    118.82
      Log pseudolikelihood =  13.41808               Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |             Semirobust
      lnrightan~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrightan~48 |
            pulse1 |
              S12. |   .4922665   .1370687     3.59   0.000     .2236168    .7609161
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .2559758   .0793784     3.22   0.001     .1003971    .4115545
              L12. |  -.4922322   .0755967    -6.51   0.000    -.6403991   -.3440653
      -------------+----------------------------------------------------------------
            /sigma |   .2062792   .0155894    13.23   0.000     .1757245    .2368338
      ------------------------------------------------------------------------------
```

A white noise test of the residuals of this final model confirms the residuals are indeed distributed according to a white noise pattern. According to Bartlett's statistic the Null hypothesis of white noise can not be rejected (0.72; p=0.68) and the dots in the figure below are all within the confidence bounds. Also, Portmanteau's test does not reject the Null hypothesis of white noise (44.03; p=0.31).

Figure 5-23: Cumulative periodogram white noise test and Bartlett's statistic of the residuals of the final pre-intervention model




The following graphs also show that the residuals of this model are normally distributed.

Figure 5-24: Standardized normal probability plot of the residuals of the final pre-intervention model

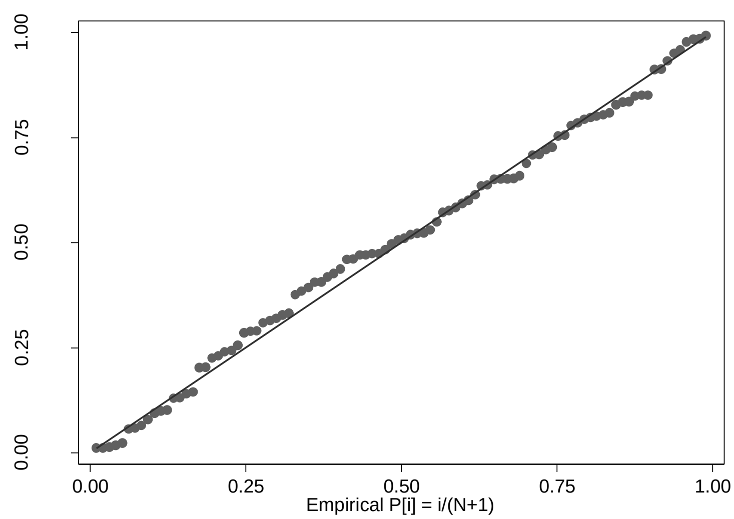
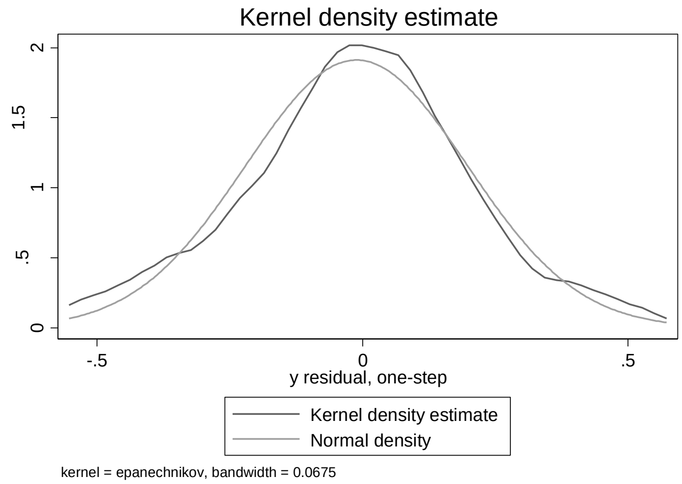


Figure 5-25: Normal density plot of the residuals of the final pre-intervention model




Finally, Figure 5-26 shows how the final model fits with the actual data of the pre-intervention series. Based on these one-step-ahead predictions, the model seems to fit the data well.

Figure 5-26: log-transformed number of right angle crashes and one-step-ahead predictions according to final model for Winnipeg excluding 48 camera intersections, pre-intervention

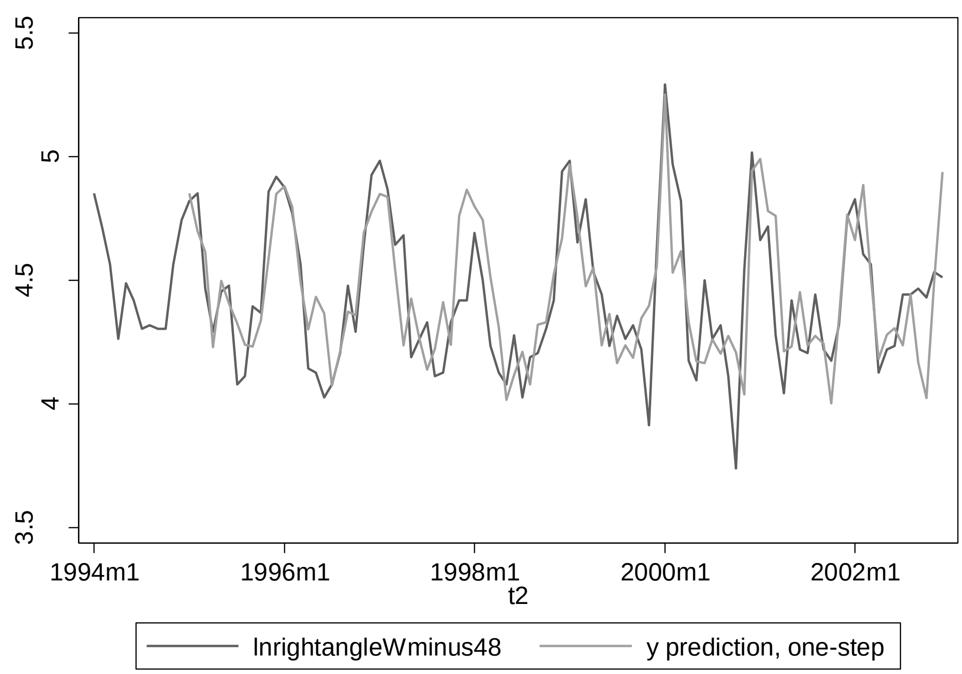
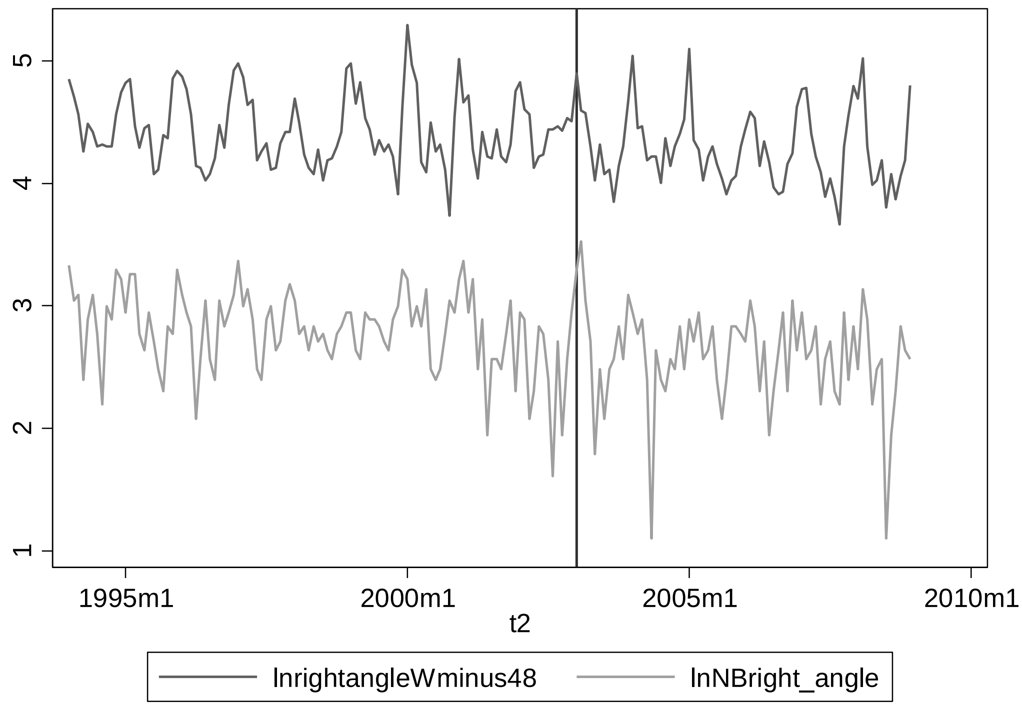


Figure 5-27 contains both series of crashes, i.e., the experimental group with right angle crashes from Winnipeg, excluding 48 camera intersections and the control group with right angle crashes from New Brunswick. The vertical line indicates the time when the first set of cameras was installed.

Figure 5-27: log-transformed number of right angle crashes in the experimental group (Winnipeg, lnrightangleWminus48) and the control group (New Brunswick, lnNBright_angle)




As can be seen in the model with the dummy variables and control group data, none of the dummy variables are associated with a significant effect, suggesting there were no spill-over effects. In other words, other intersections in the city without cameras did not seem to have benefitted from the decrease in right-angle crashes apparent at the camera intersections. By the same token, these intersections without cameras also did not seem to have experienced an increase in right-angle crashes due to displacement behaviour of drivers.

Note that the AR terms are significant in the model with the control group data so only this model is presented.

In conclusion, the results from this analysis suggest there were no spill-over effects on right angle crashes in Winnipeg associated with the installation of cameras.

```
ARIMA regression

      Sample:  1995m1 - 2008m12                        Number of obs      =       168
                                                       Wald chi2(9)       =    168.63
      Log pseudolikelihood =  35.11596                 Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |             Semirobust
      lnrightan~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrightan~48 |
            pulse1 |
              S12. |   .4895539   .1457516     3.36   0.001      .203886    .7752218
                   |
            pulse2 |
              S12. |   .4139478   .1503946     2.75   0.006     .1191798    .7087159
                   |
      lnNBright_~e |
              S12. |    .037102   .0424166     0.87   0.382    -.0460329     .120237
                   |
            dummy1 |
              S12. |    .003023   .0858848     0.04   0.972     -.165308    .1713541
                   |
            dummy2 |
              S12. |  -.0782275   .0853357    -0.92   0.359    -.2454823    .0890274
                   |
            dummy3 |
              S12. |  -.0681208     .05878    -1.16   0.246    -.1833275    .0470858
                   |
            dummy4 |
              S12. |  -.0353028   .0601093    -0.59   0.557    -.1531148    .0825091
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .2808254   .0642348     4.37   0.000     .1549275    .4067233
              L12. |  -.4684461   .0622271    -7.53   0.000    -.5904091   -.3464832
      -------------+----------------------------------------------------------------
            /sigma |   .1943036    .010561    18.40   0.000     .1736045    .2150028
      ------------------------------------------------------------------------------
```

**Rear end crashes in Winnipeg.** As can be seen in Figure 5-28, there are many outliers in this series of rear end crashes in Winnipeg excluding the 48 camera intersections. The variance also changes over time. For these reasons the analyses will be conducted using the log-transformed data. No shifts around the time of installing the cameras are visible with the naked eye.

Table 5-7 contains information about rear end crashes in Winnipeg, excluding 48 camera intersections, before and after installation of cameras. The monthly average of rear end crashes is higher after installation of each set of cameras, although the difference is smaller for later interventions.

Figure 5-28: Number of rear end crashes in Winnipeg, excluding 48 camera intersections from January 1994 through December 2008

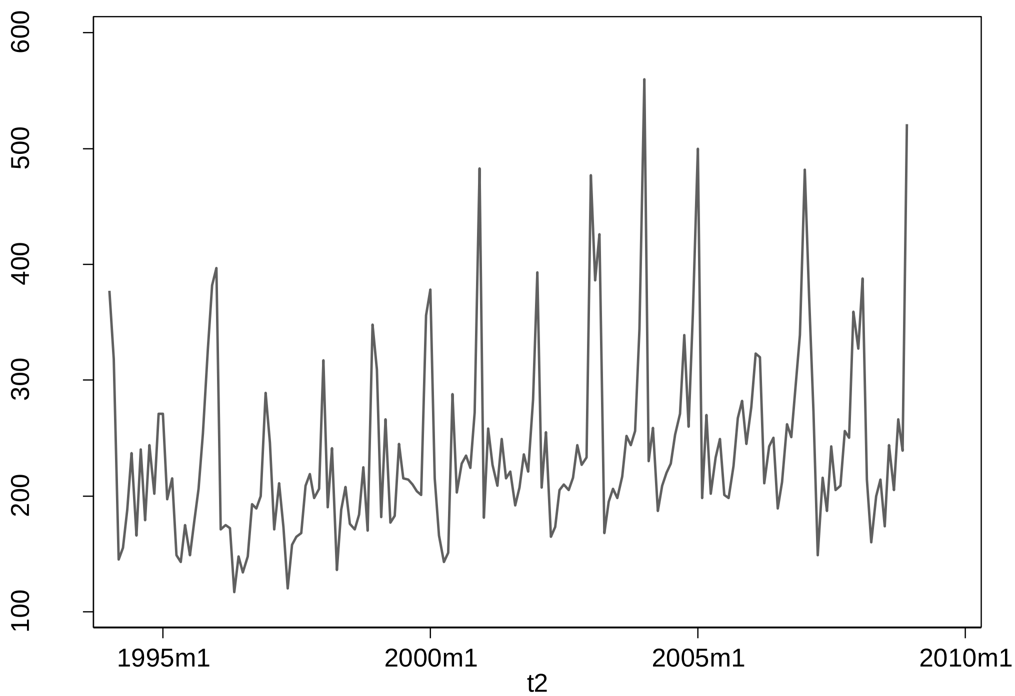
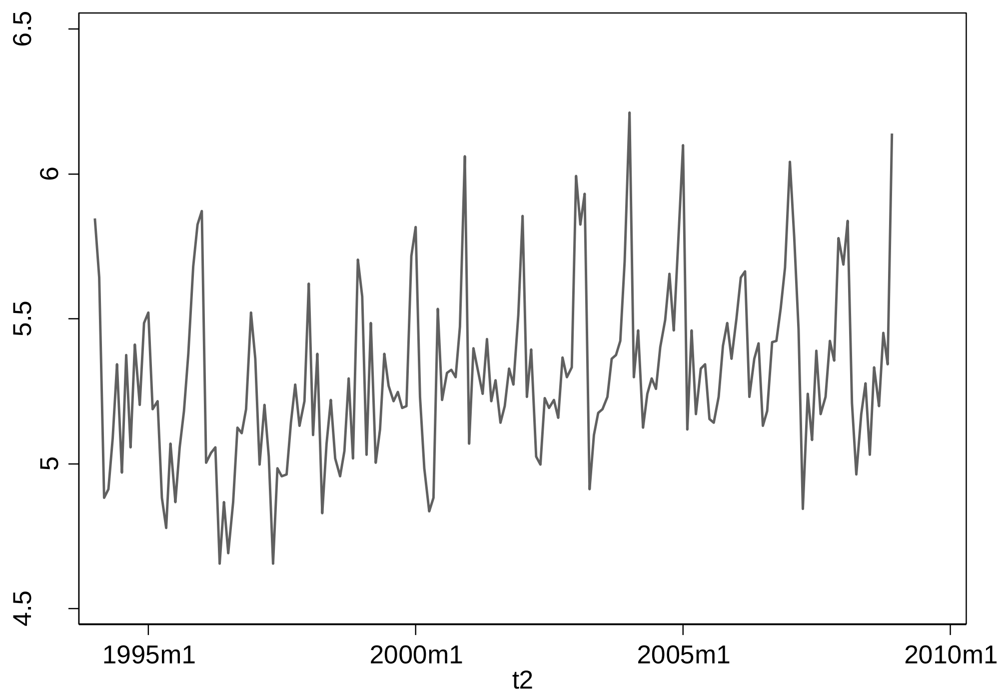



Table 5-7: Monthly average of rear end crashes and standard deviation before and after installation of cameras in Winnipeg, excluding 48 camera intersections

| **Time period** | **# of observations (in months)** | **Mean of rear end crashes** | **Std. Dev.** |
|---|---|---|---|
| *First set of 12 cameras* | | | |
| Jan. 1994 - Dec. 2002 (before) | 108 | 193.00 | 58.44 |
| Jan. 2003 - Dec. 2008 (after) | 72 | 234.96 | 78.07 |
| *Second set of 12 cameras* | | | |
| Jan. 1994 - Jul. 2003 (before) | 115 | 196.67 | 63.99 |
| Aug. 2003 - Dec. 2008 (after) | 65 | 232.98 | 74.22 |
| *Third set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2004 (before) | 126 | 200.38 | 67.58 |
| Jul. 2004 - Dec. 2008 (after) | 54 | 231.72 | 70.88 |
| *Fourth set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2005 (before) | 138 | 204.21 | 69.21 |
| Jul. 2005 - Dec. 2008 (after) | 42 | 228.10 | 69.77 |

When looking at the log transformed crash numbers, no strong intervention effect is apparent (see Figure 5-29). Comparable to previous analyses, the final model will be based on the pre-intervention series only. This pre-intervention series is fairly flat, suggesting there is no need to difference the data locally (as with previous models, this was confirmed with a formal test: 0.0002; p=0.871).

Figure 5-29: Log of the number of rear end crashes in Winnipeg, excluding 48 camera intersections from January 1994 through December 2008




On the other hand, the autocorrelation and partial autocorrelation of the log transformed, pre-intervention series show a fairly strong seasonal effect, comparable to the pattern of right angle crashes in Winnipeg minus 48 camera intersections (see correlogram in Table 5-8). For this reason the data will be seasonally differenced.

The autocorrelation and partial autocorrelation of the log transformed, seasonally differenced rear end crashes in Winnipeg, excluding 48 camera intersections can be seen in Figures 5-30 and 5-31.

Table 5-8: Autocorrelation and partial autocorrelation of the pre-intervention log transformed number of rear end crashes in Winnipeg, excluding 48 camera intersections

```
                                          -1       0       1 -1       0       1
 LAG       AC       PAC      Q     Prob>Q  [Autocorrelation]  [Partial Autocor]
-------------------------------------------------------------------------------
1       0.3678   0.3683   15.02  0.0001          |--                |--
2       0.1733   0.0513  18.386  0.0001          |-                 |
3       0.0324  -0.0696  18.505  0.0003          |                  |
4      -0.2062  -0.2587  23.363  0.0001         -|                --|
5      -0.1648  -0.0129  26.495  0.0001         -|                  |
6      -0.1713  -0.0287  29.914  0.0000         -|                  |
7      -0.2295  -0.1594  36.108  0.0000         -|                 -|
8      -0.2165  -0.1595  41.674  0.0000         -|                 -|
9       0.0292   0.2119  41.776  0.0000          |                  |-
10      0.1729   0.2133  45.399  0.0000          |-                 |-
11      0.3468   0.1731  60.129  0.0000          |--                |-
12      0.4963   0.2702  90.616  0.0000          |---               |--
13      0.3011   0.0726  101.95  0.0000          |--                |
14      0.1466  -0.0305  104.67  0.0000          |-                 |
15      0.0839   0.0518  105.57  0.0000          |                  |
16     -0.1609  -0.1364  108.91  0.0000         -|                 -|
17     -0.1652  -0.0288  112.47  0.0000         -|                  |
18     -0.1415   0.0669  115.12  0.0000         -|                  |
19     -0.2204  -0.0014   121.6  0.0000         -|                  |
20     -0.2247  -0.1856  128.42  0.0000         -|                 -|
21      0.0046   0.0701  128.42  0.0000          |                  |
22      0.0610  -0.0188  128.94  0.0000          |                  |
23      0.2870   0.1919  140.45  0.0000          |--                |-
24      0.4233   0.1173  165.79  0.0000          |---               |
25      0.1413  -0.1653  168.65  0.0000          |-                -|
26      0.1286   0.0168  171.04  0.0000          |-                 |
27     -0.0099  -0.1629  171.05  0.0000          |                 -|
28     -0.1555  -0.1207  174.65  0.0000         -|                  |
29     -0.1729  -0.2339  179.14  0.0000         -|                 -|
30     -0.1647  -0.1256  183.27  0.0000         -|                 -|
31     -0.2037   0.0509  189.67  0.0000         -|                  |
32     -0.2340  -0.2487  198.23  0.0000         -|                 -|
33     -0.0171  -0.0033  198.28  0.0000          |                  |
34      0.0030  -0.0357  198.28  0.0000          |                  |
35      0.1493  -0.0732  201.91  0.0000          |-                 |
36      0.2299  -0.0548  210.63  0.0000          |-                 |
37      0.0937   0.1137   212.1  0.0000          |                  |
38      0.0742  -0.0224  213.03  0.0000          |                  |
39     -0.0541  -0.1680  213.54  0.0000          |                 -|
40     -0.1948  -0.2538  220.17  0.0000         -|                --|
```

Figure 5-30: Autocorrelation of pre-intervention log-transformed, seasonally differenced rear end crash series in Winnipeg, excluding 48 camera intersections

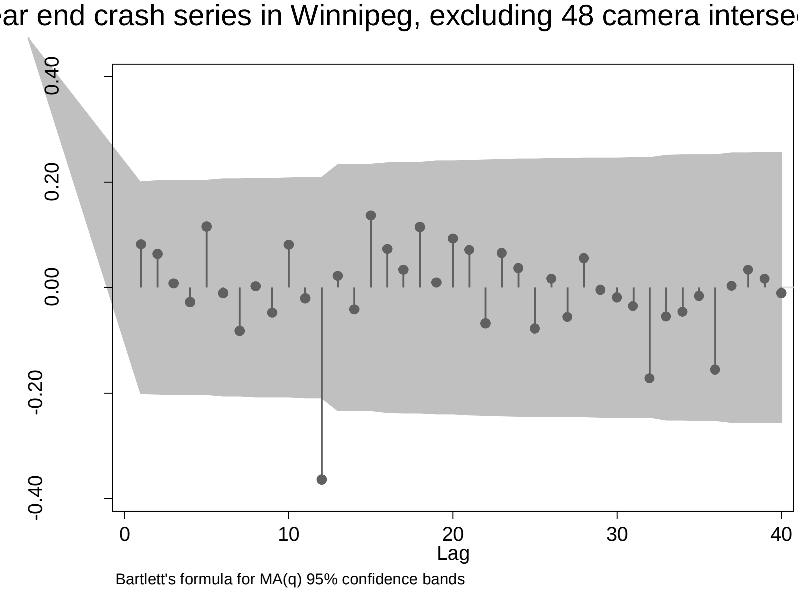
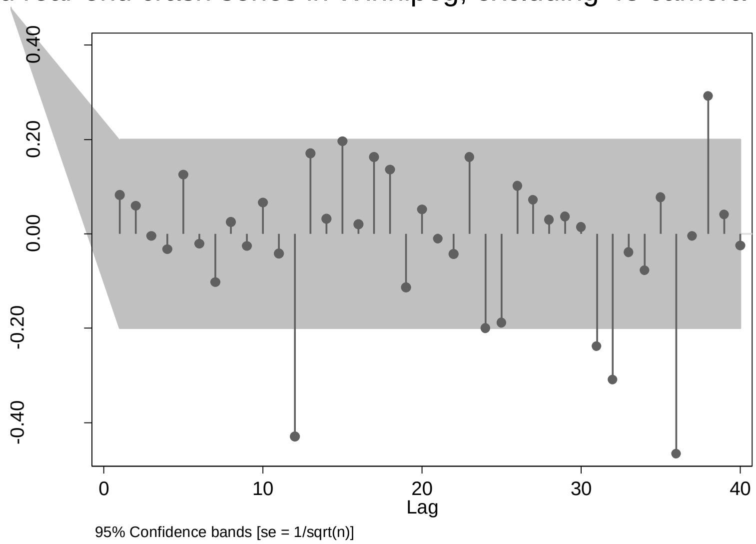


Figure 5-31: Partial autocorrelation of pre-intervention log-transformed, seasonally differenced rear end crash series in Winnipeg, excluding 48 camera intersections




The following model was found with the lowest AIC and BIC values (-4.85 and 5.41 respectively), as well as significant ARMA terms that are within the bounds of stationarity and invertibility. As before, the ARMA structure is autoregressive with no moving average components. Results of this model were consistent with those of a model only containing the seasonal AR term.

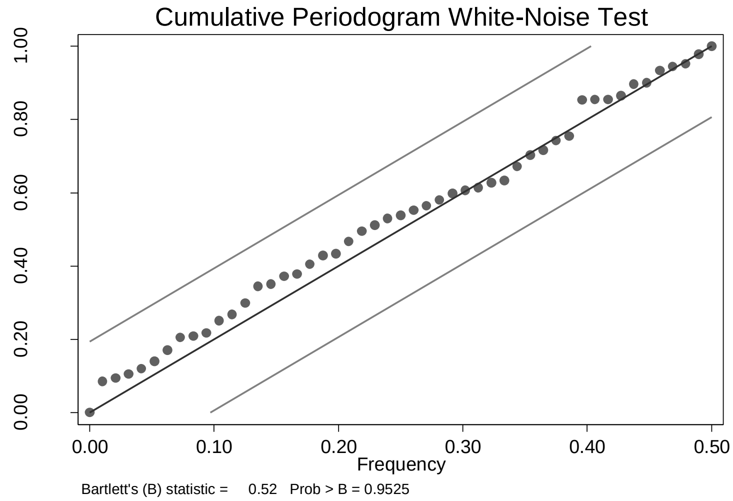
```
ARIMA regression

      Sample:  1995m1 - 2002m12                        Number of obs      =        96
                                                       Wald chi2(3)       =     19.58
      Log pseudolikelihood =   6.42345                 Prob > chi2        =    0.0002

      ------------------------------------------------------------------------------
      S12.         |              Semirobust
      lnrearend~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrearend~48 |
            pulse1 |
              S12. |   .5758095   .2175274     2.65   0.008     .1494636    1.002155
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .1587427   .1069673     1.48   0.138    -.0509093    .3683947
              L12. |  -.4543596   .1122741    -4.05   0.000    -.6744127   -.2343064
      -------------+----------------------------------------------------------------
            /sigma |   .2229048   .0145388    15.33   0.000     .1944092    .2514003
      ------------------------------------------------------------------------------
```

A white noise test of the residuals of this final model confirms the residuals are indeed distributed according to a white noise pattern. According to Bartlett's statistic the Null hypothesis of white noise can not be rejected (0.52; p=0.95) and the dots in the figure below are all within the confidence bounds. Also, Portmanteau's test does not reject the Null hypothesis of white noise (27.53; p=0.93).

Figure 5-32: Cumulative periodogram white noise test and Bartlett's statistic of the residuals of the final pre-intervention model




The following graphs also show that the residuals of this model are normally distributed.

Figure 5-33: Standardized normal probability plot of the residuals of the final pre-intervention model

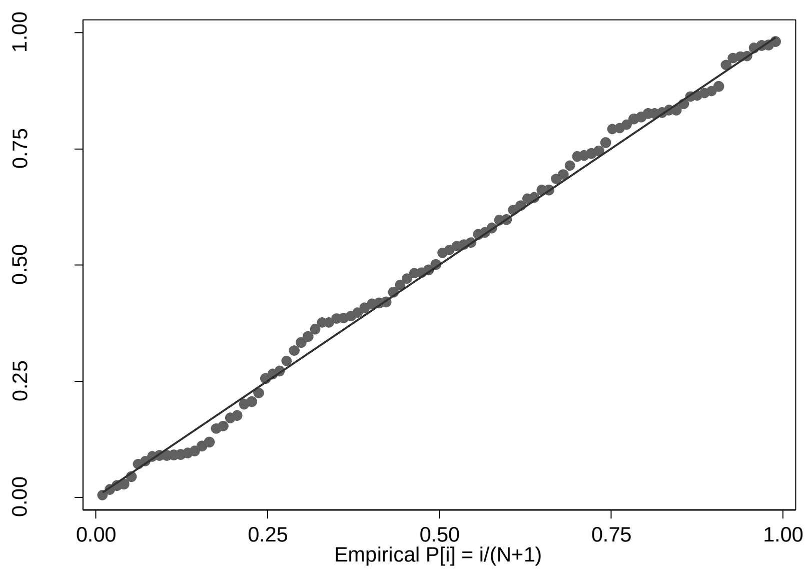
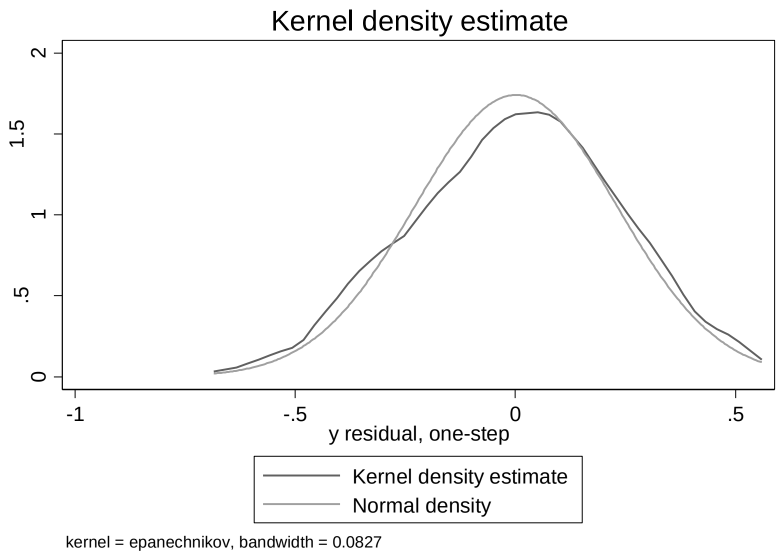


Figure 5-34: Normal density plot of the residuals of the final pre-intervention model




Finally, Figure 5-35 shows how the final model fits with the actual data of the pre-intervention series. Based on these one-step-ahead predictions, the model seems to fit the data well.

Figure 5-35: log-transformed number of rear end crashes and one-step-ahead predictions according to final model for Winnipeg, excluding 48 camera intersections, pre-intervention

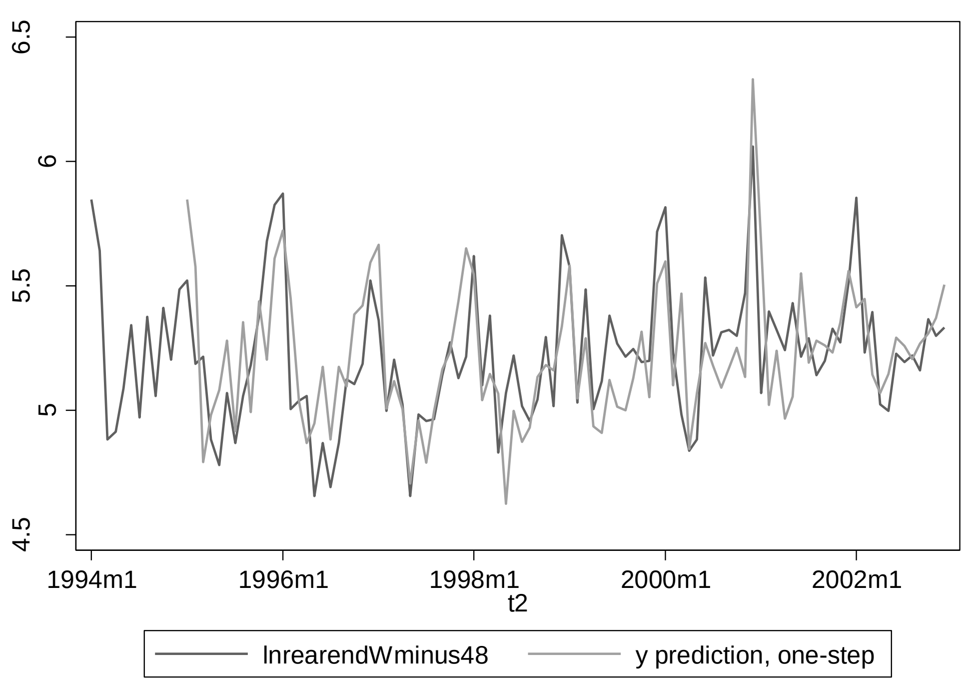
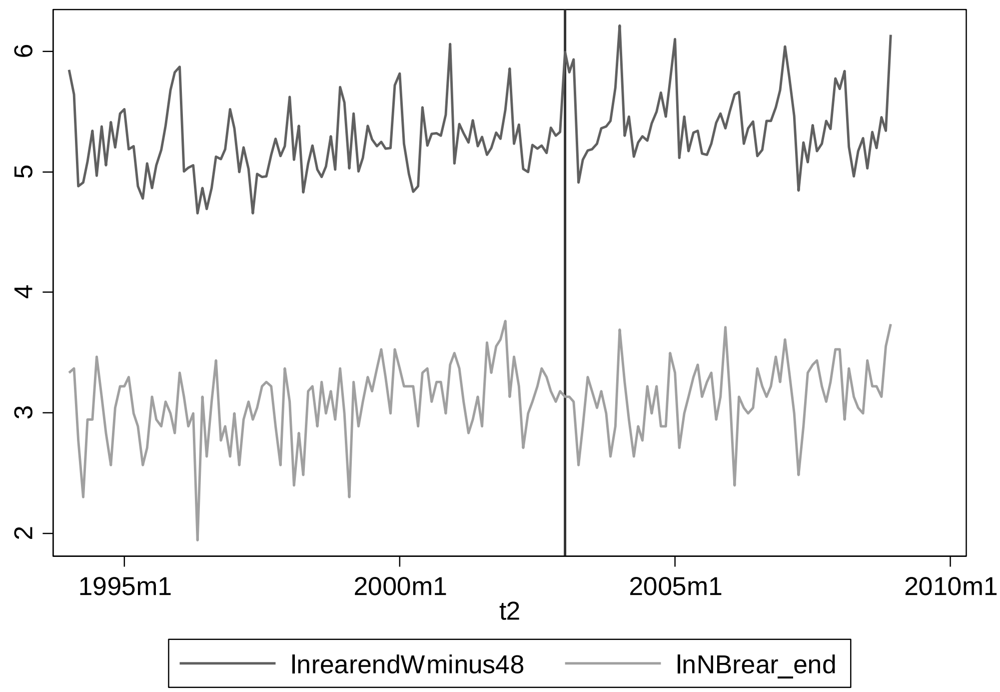


Figure 5-36 contains both series of crashes, i.e., the experimental group with rear end crashes from Winnipeg, excluding 48 camera intersections and the control group with rear end crashes from New Brunswick. The vertical line indicates the time when the first set of cameras was installed.

Figure 5-36: log-transformed number of rear end crashes in the experimental group (Winnipeg, lnrearendWminus48) and the control group (New Brunswick, lnNBrear_end)




As can be seen in the model with the dummy variables and control group data, only one effect is significant at the 10% level (rather than 5%). The installation of the first set of cameras was associated with a 25.36% increase in rear end crashes at the other intersections in Winnipeg without cameras (0.226; p=0.051). Following this initial increase there are no further significant effects associated with the installation of more cameras. A model with only the significant AR 12 term was tested as well. Results were consistent although the effect in this model is significant at the 5% level (0.217; p=0.040).

It is possible that this initial increase is indeed the result of a spill-over effect, i.e., drivers who incorrectly assumed that cameras were present at these intersections as a result of advertising the photo enforcement program may have used their brakes abruptly when approaching an intersection for fear of being fined. Further monitoring will be necessary to confirm this.

```
ARIMA regression

      Sample:  1995m1 - 2008m12                         Number of obs      =       168
                                                        Wald chi2(9)       =     41.92
      Log pseudolikelihood =  19.45072                  Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |             Semirobust
      lnrearend~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnrearend~48 |
            pulse1 |
              S12. |   .5733314   .2013569     2.85   0.004     .1786791    .9679838
                   |
            pulse2 |
              S12. |   .2548105   .1732629     1.47   0.141    -.0847786    .5943996
                   |
      lnNBrear_end |
              S12. |   .1118799   .0670222     1.67   0.095    -.0194811    .2432409
                   |
            dummy1 |
              S12. |   .2261205   .1158557     1.95   0.051    -.0009525    .4531935
                   |
            dummy2 |
              S12. |  -.0707467   .0982779    -0.72   0.472    -.2633678    .1218745
                   |
            dummy3 |
              S12. |   .0489681   .0670308     0.73   0.465    -.0824099    .1803461
                   |
            dummy4 |
              S12. |  -.0643447   .0697473    -0.92   0.356     -.201047    .0723575
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .1346921   .0872624     1.54   0.123    -.0363391    .3057232
              L12. |  -.4531767   .0865048    -5.24   0.000     -.622723   -.2836304
      -------------+----------------------------------------------------------------
            /sigma |   .2136914   .0117159    18.24   0.000     .1907286    .2366542
      ------------------------------------------------------------------------------
```

### 5.3.3 Speeding at 48 camera intersections

This section contains the results from analyses using crash data related to speeding coming from 48 intersections in the city of Winnipeg where photo enforcement cameras are used. To increase the likelihood that the crashes under scrutiny in this section about speeding could logically have been the result of speeding behaviour, only crashes during non-peak periods have been included in these analyses (i.e., all crashes during the weekend and crashes between 9:00am-16pm and between 19:00pm-6:00am). Selecting crashes according to this criterion can be justified based on the knowledge that many drivers are stuck in traffic jams during peak hours and would therefore not be able to freely choose the speed at which they want to drive. Furthermore, crashes where one or more drivers were reversing, parked or entering the parked position have also been excluded.

Instead of distinguishing crashes based on crash configuration (right angle crashes versus rear end crashes as in the previous sections about red light running) crashes in the analyses for speeding are now grouped into categories of severity: injury crashes and property damage only (pdo) crashes. Fatal crashes have not been analyzed because many monthly counts — if not all — for this type of crashes are zero so no meaningful conclusions from these data can be drawn.

**Injury crashes at 48 camera intersections.** Figure 5-37 shows the number of injury crashes at all 48 intersections in Winnipeg where photo enforcement cameras are used for the period of January 1994 through December 2008. As can be seen in this figure, there are several outliers and the variance of this crash series changes over time, with less variability after the intervention. To mitigate the effect of these outliers as well as the changing variance over time, raw crash numbers have been log-transformed and further analyses have been conducted on these transformed data.

It is also apparent from this figure that the pattern at the outset of this series differs from the pattern passed July 1997: before this point there appears to be a decreasing trend with extreme outliers whereas the series is flatter and better behaved after this point. For this reason, data from before August 1997 will not be used in this analysis, not to build the pre-intervention model, nor to test the impact of the dummy variables associated with the use of cameras.

Figure 5-37: Number of injury crashes in Winnipeg at 48 intersections with cameras from January 1994 through December 2008

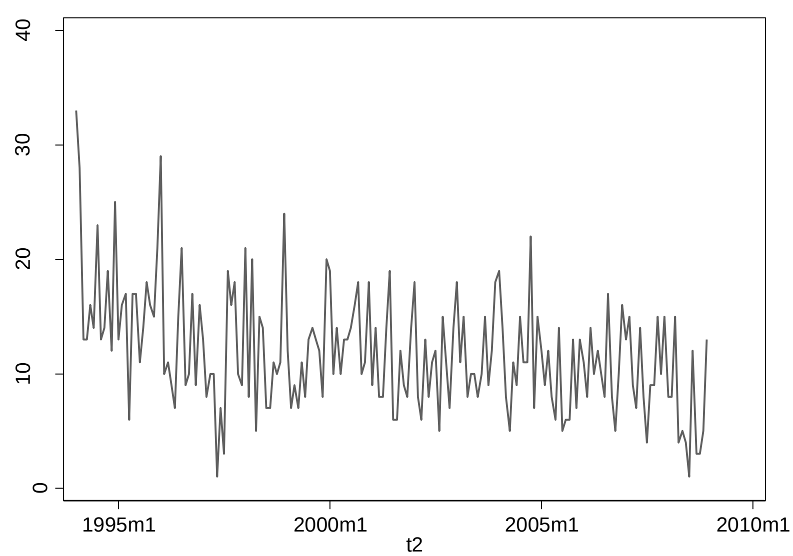


Table 5-9 reveals that the monthly average of injury crashes after installation of each set of cameras is lower than before installation. It appears that the strongest effect is associated with the installation of the fourth set of cameras (11.92 minus 9.24), although the differences between the before/after effects are not great.

Table 5-9: Monthly average of injury crashes and standard deviation before and after installation of cameras at 48 intersections with cameras (note that data from before August 1997 are not included)

| Time period | # of observations (in months) | Mean of injury crashes | Std. Dev. |
|---|---|---|---|
| *First set of 12 cameras* | | | |
| Aug. 1997 - Dec. 2002 (before) | 65 | 12.00 | 4.42 |
| Jan. 2003 - Dec. 2008 (after) | 72 | 10.28 | 4.26 |
| *Second set of 12 cameras* | | | |
| Aug. 1997 - Jul. 2003 (before) | 72 | 11.94 | 4.34 |
| Aug. 2003 - Dec. 2008 (after) | 65 | 10.15 | 4.32 |
| *Third set of 12 cameras* | | | |
| Aug. 1997 - Jun. 2004 (before) | 83 | 11.93 | 4.31 |
| Jul. 2004 - Dec. 2008 (after) | 54 | 9.81 | 4.29 |
| *Fourth set of 12 cameras* | | | |
| Aug. 1997 - Jun. 2005 (before) | 95 | 11.92 | 4.29 |
| Jul. 2005 - Dec. 2008 (after) | 42 | 9.24 | 4.14 |

Figure 5-38 shows the log of the number of injury crashes at all 48 intersections in Winnipeg where photo enforcement cameras are used for the period of August 1997 through December 2008. As can be seen, there is no apparent strong up- or downward trend in the pre-intervention series (August 1997 through December 2002), which suggests the data do not have to be differenced locally before analyzing them. This was confirmed with a formal test of a linear trend in the final pre-intervention model (-0.002; p=0.763). There appears to be at least one more outlier toward the end of the series, despite the log-transformation. Pulse variables will be used to reduce the impact of outliers.

Also, as can be seen in the correlogram (see Table 5-10), there is no strong seasonal variation, suggesting seasonal differencing is not required either.

Figure 5-38: Log of the number of injury crashes in Winnipeg at 48 intersections with cameras from August 1997 through December 2008

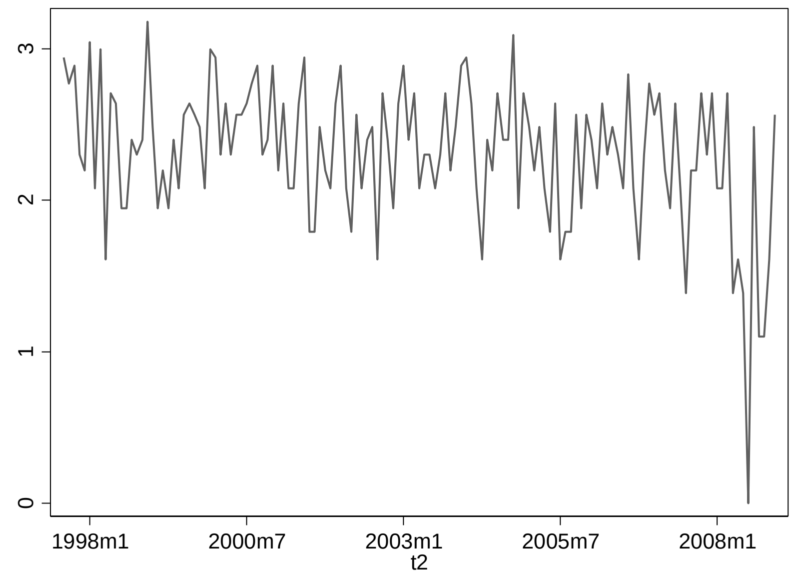



Table 5-10: Autocorrelation and partial autocorrelation of the pre-intervention log transformed number of injury crashes at 48 camera intersections

```
                                                  -1       0       1 -1       0       1
 LAG       AC        PAC        Q      Prob>Q  [Autocorrelation]  [Partial Autocor]
-------------------------------------------------------------------------------
1       -0.0785   -0.0792    .41947   0.5172          |                  |
2       -0.0729   -0.0823    .78691   0.6747          |                  |
3        0.1296    0.1170    1.9666   0.5794          |-                 |
4       -0.0236   -0.0069    2.0063   0.7346          |                  |
5        0.0583    0.0860    2.2532   0.8131          |                  |
6        0.0178    0.0216    2.2765   0.8926          |                  |
7        0.1003    0.1328    3.0319   0.8820          |                  |-
8       -0.0014    0.0090    3.0321   0.9323          |                  |
9        0.0729    0.1248    3.4452   0.9440          |                  |
10      -0.0906   -0.1623     4.095   0.9430          |                 -|
11      -0.0724   -0.0278    4.5182   0.9522          |                  |
12       0.1092    0.0936    5.4978   0.9393          |                  |
13      -0.0411   -0.0501    5.6391   0.9583          |                  |
14      -0.0550   -0.0738    5.8971   0.9690          |                  |
15      -0.0920   -0.1724    6.6342   0.9670          |                 -|
16       0.0880    0.1028    7.3219   0.9665          |                  |
17      -0.1255   -0.2116    8.7501   0.9478         -|                 -|
18      -0.1649   -0.1465     11.27   0.8826         -|                 -|
19      -0.0175   -0.1271    11.299   0.9134          |                 -|
20      -0.1973   -0.3117    15.065   0.7727         -|                --|
21       0.0351    0.0187    15.187   0.8135          |                  |
22      -0.0603   -0.1800    15.554   0.8374          |                 -|
23      -0.0818   -0.0302    16.249   0.8444          |                  |
24       0.0961    0.1438    17.229   0.8387          |                  |-
25      -0.0765   -0.1427    17.866   0.8480          |                 -|
26      -0.0764   -0.1166    18.518   0.8561          |                  |
27      -0.0260   -0.2360    18.595   0.8843          |                 -|
28       0.0562   -0.1859    18.967   0.8992          |                 -|
29       0.0350   -0.0769    19.115   0.9183          |                  |
30       0.1418    0.5078    21.618   0.8676          |-                 |----
```

The autocorrelation and partial autocorrelation of the pre-intervention series can also be seen in Figures 5-39 and 5-40.

Figure 5-39: Autocorrelation of pre-intervention log-transformed injury crashes

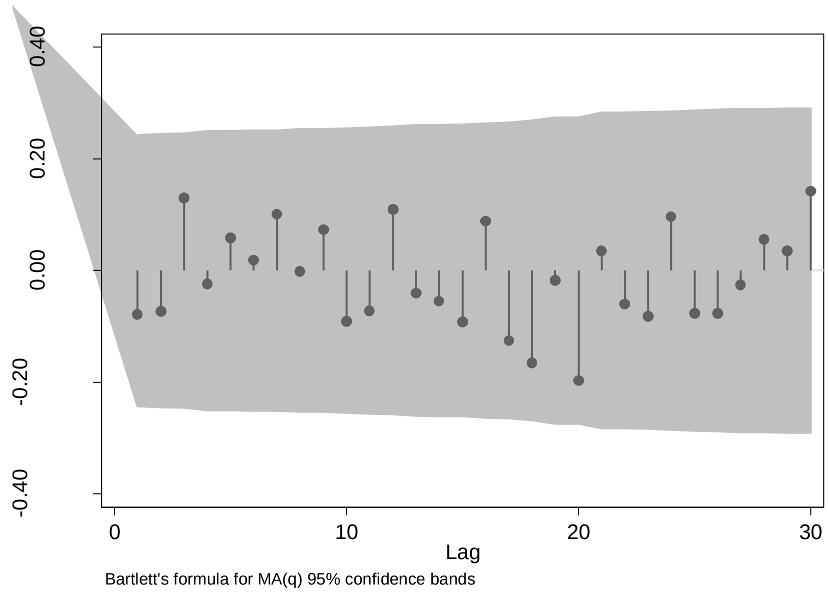
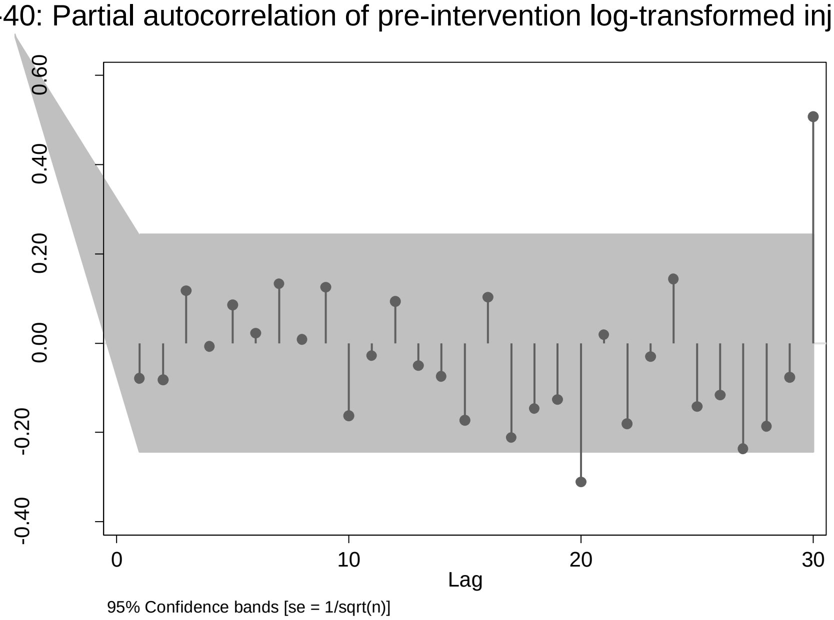



Figure 5-40: Partial autocorrelation of pre-intervention log-transformed injury crashes




Several models that were considered viable based on the information from the autocorrelation and partial autocorrelation plots were compared to one another using AIC and BIC as well as the significant values of the ARIMA structure. The following model was found with the lowest AIC and BIC values (89.13 and 95.65 respectively), as well as significant ARMA terms that are within the bounds of stationarity and invertibility.

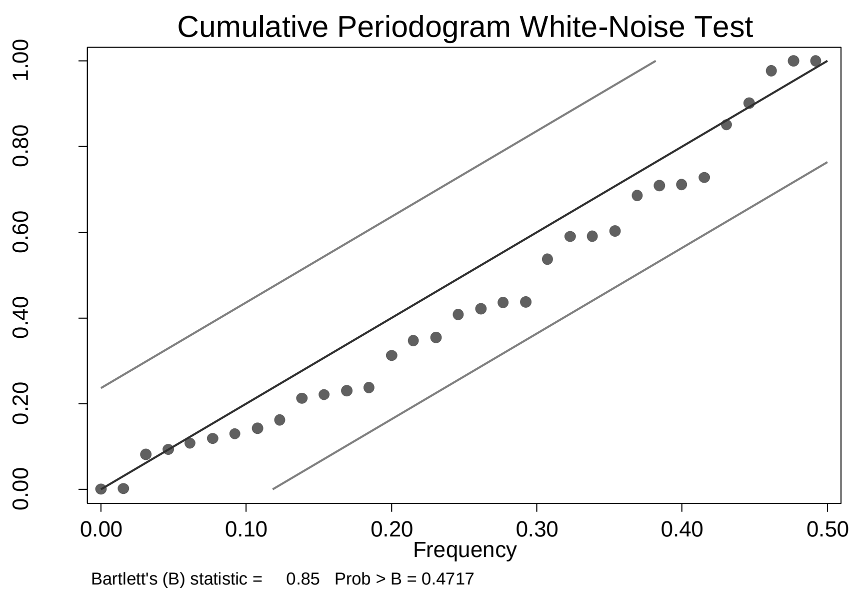
```
ARIMA regression

      Sample:  1997m8 - 2002m12                      Number of obs      =         65
                                                     Wald chi2(2)       = 326103.25
      Log pseudolikelihood = -41.56467               Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
                   |              Semirobust
        lninjury48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |    .398048   .0889927     4.47   0.000     .2236254    .5724705
              L12. |   .5997729   .0890644     6.73   0.000     .4252098    .7743359
      -------------+----------------------------------------------------------------
            /sigma |   .4200558   .0315505    13.31   0.000     .3582179    .4818936
      ------------------------------------------------------------------------------
```

A white noise test of the residuals of this final model confirms the residuals are indeed distributed according to a white noise pattern. According to Bartlett's statistic the Null hypothesis of white noise can not be rejected (0.85; p=0.47) and the dots in the figure below are all within the confidence bounds. Also, Portmanteau's test does not reject the Null hypothesis of white noise (25.40; p=0.71).

Figure 5-41: Cumulative periodogram white noise test and Bartlett's statistic of the residuals of the final pre intervention model




The following graphs also show that the residuals of this model are normally distributed.

Figure 5-42: Standardized normal probability plot of the residuals of the final pre intervention model

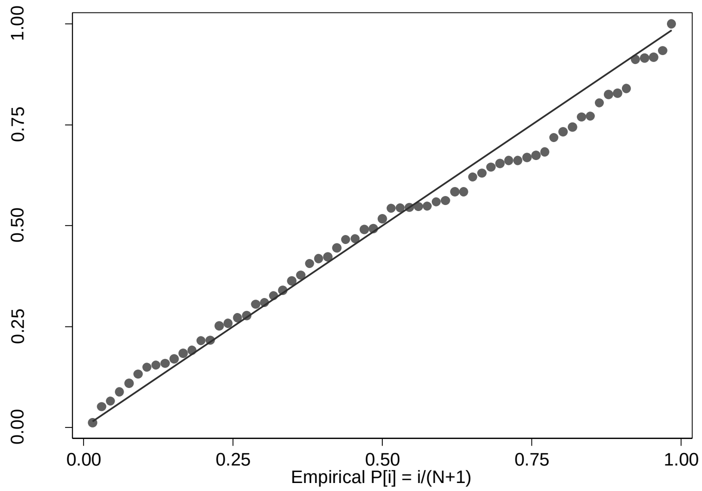
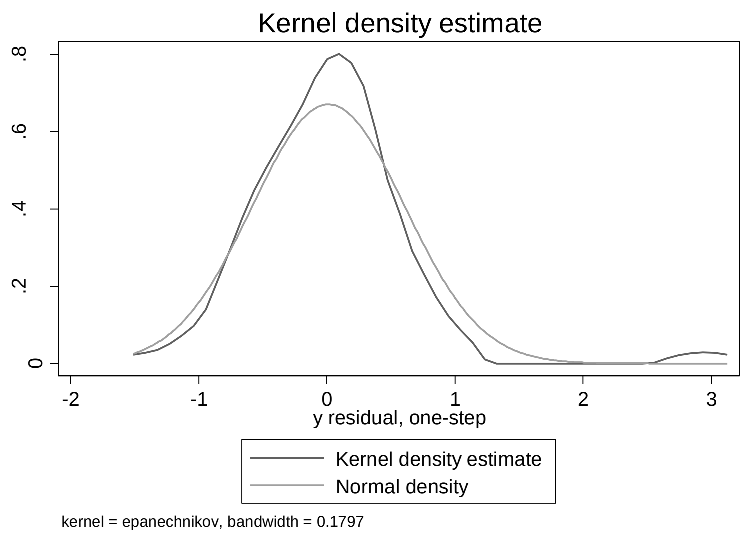



Figure 5-43: Normal density plot of the residuals of the final pre intervention model




Finally, Figure 5-44 shows how the final model fits with the actual data of the pre-intervention series. Based on these one-step-ahead predictions, the model seems to fit the data reasonably well.

Figure 5-44: log-transformed number of injury crashes and one-step-ahead predictions according to final model for 48 intersections with cameras, pre-intervention

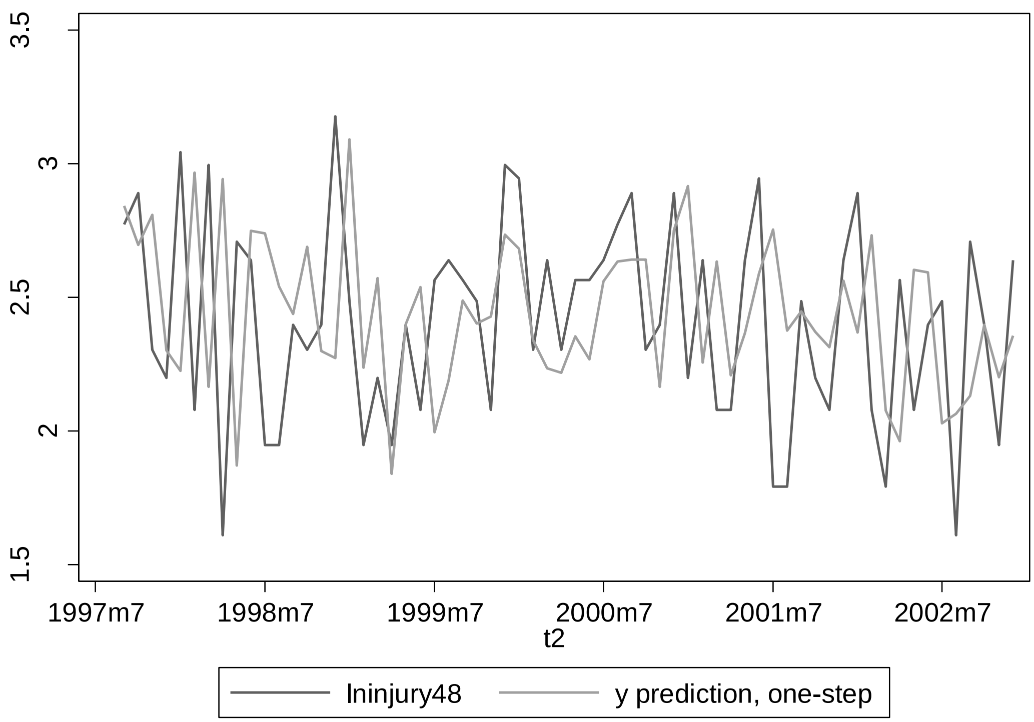
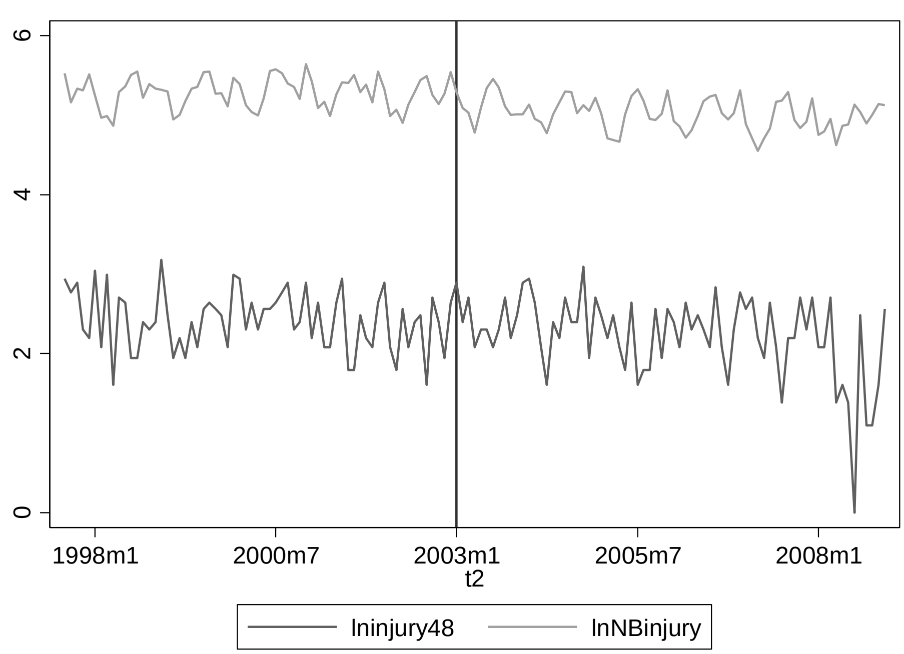



Figure 5-45 contains the experimental group with injury crashes from Winnipeg and the control group with injury crashes from New Brunswick.

Figure 5-45: log-transformed number of injury crashes in the experimental group (Winnipeg, lninjury48) and the control group (New Brunswick, lnNBinjury)



As can be seen in the model with the dummy variables and control group data, only the installation of the fourth set of cameras was associated with a significant effect (at the 10% level). The installation of this last set of cameras led to a 23.51% decrease in injury crashes at camera intersections (-0.268; p=0.053). The AR terms are also no longer significant in this model. When looking at the same model excluding the control group data, the AR terms are significant again but the dummy variable is no longer significant.

ARIMA regression with control group

Sample: 1997m8 - 2008m12 | Number of obs = 137
Wald chi2(8) = 3844.23
Log pseudolikelihood = -64.49875 | Prob > chi2 = 0.0000

| lninjury48 | Coef. | Semirobust Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lninjury48 | | | | | | |
| pulse1 | -2.116211 | .1238412 | -17.09 | 0.000 | -2.358935 | -1.873487 |
| lnNBinjury | .456949 | .0102684 | 44.50 | 0.000 | .4368234 | .4770747 |
| dummy1 | .0443956 | .1310901 | 0.34 | 0.735 | -.2125362 | .3013275 |
| dummy2 | .0598835 | .1593379 | 0.38 | 0.707 | -.2524132 | .3721801 |
| dummy3 | .0214457 | .1512776 | 0.14 | 0.887 | -.2750529 | .3179443 |
| dummy4 | -.2675211 | .1383762 | -1.93 | 0.053 | -.5387335 | .0036912 |
| ARMA | | | | | | |
| ar | | | | | | |
| L1. | .1091826 | .0944852 | 1.16 | 0.248 | -.076005 | .2943702 |
| L12. | .0584564 | .0968801 | 0.60 | 0.546 | -.131425 | .2483378 |
| /sigma | .3873957 | .0211204 | 18.34 | 0.000 | .3460004 | .428791 |

ARIMA regression without control group

Sample: 1997m8 - 2008m12 | Number of obs = 137
Wald chi2(7) = 56924.82
Log pseudolikelihood = -87.32299 | Prob > chi2 = 0.0000

| lninjury48 | Coef. | Semirobust Std. Err. | z | P>\|z\| | [95% Conf. | Interval] |
|---|---|---|---|---|---|---|
| lninjury48 | | | | | | |
| pulse1 | -1.636135 | .3025092 | -5.41 | 0.000 | -2.229043 | -1.043228 |
| dummy1 | .1131474 | .1692497 | 0.67 | 0.504 | -.2185759 | .4448708 |
| dummy2 | .1162612 | .191937 | 0.61 | 0.545 | -.2599284 | .4924507 |
| dummy3 | .1127471 | .2298368 | 0.49 | 0.624 | -.3377248 | .563219 |
| dummy4 | -.295915 | .2272153 | -1.30 | 0.193 | -.7412487 | .1494188 |
| ARMA | | | | | | |
| ar | | | | | | |
| L1. | .4598199 | .0705258 | 6.52 | 0.000 | .3215918 | .5980479 |
| L12. | .536609 | .0706858 | 7.59 | 0.000 | .3980674 | .6751506 |
| /sigma | .4420959 | .0241837 | 18.28 | 0.000 | .3946968 | .489495 |

**Property damage only (pdo) crashes at 48 camera intersections**. Figure 5-46 shows the number of pdo crashes at all 48 intersections in Winnipeg where photo enforcement cameras are used for the period of January 1994 through December 2008. As can be seen in this figure, there are several outliers and the variance of this crash series changes over time, with more variability after the intervention, so log-transformed data will be used.

Table 5-11 reveals that the monthly average of pdo crashes after installation of the first three sets of cameras is slightly higher than before installation. There is virtually no before/after difference associated with the installation of the last set of cameras.

Figure 5-46: Number of pdo crashes in Winnipeg at 48 intersections with cameras from January 1994 through December 2008

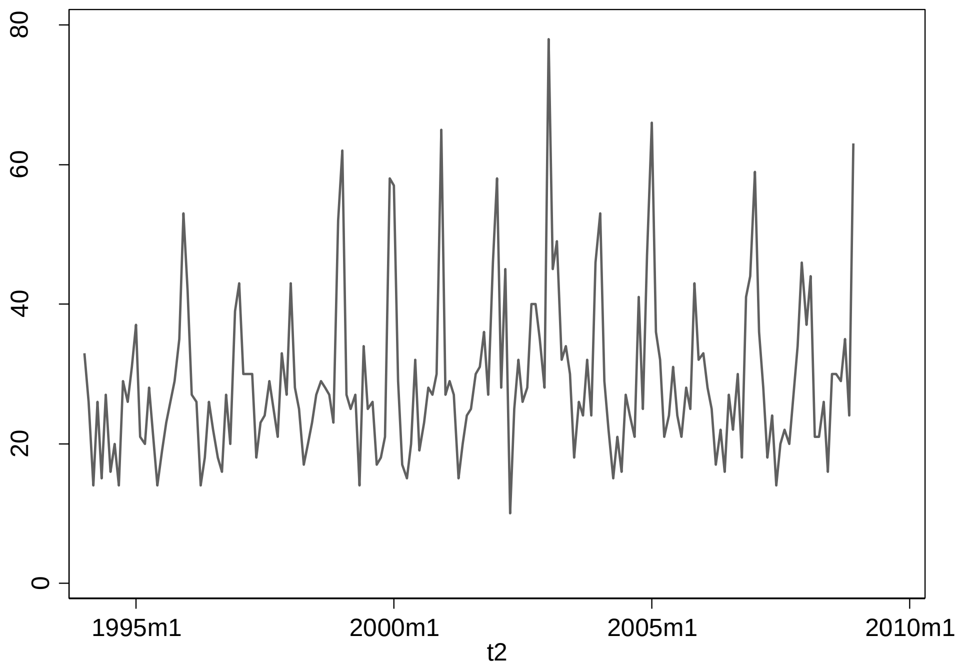
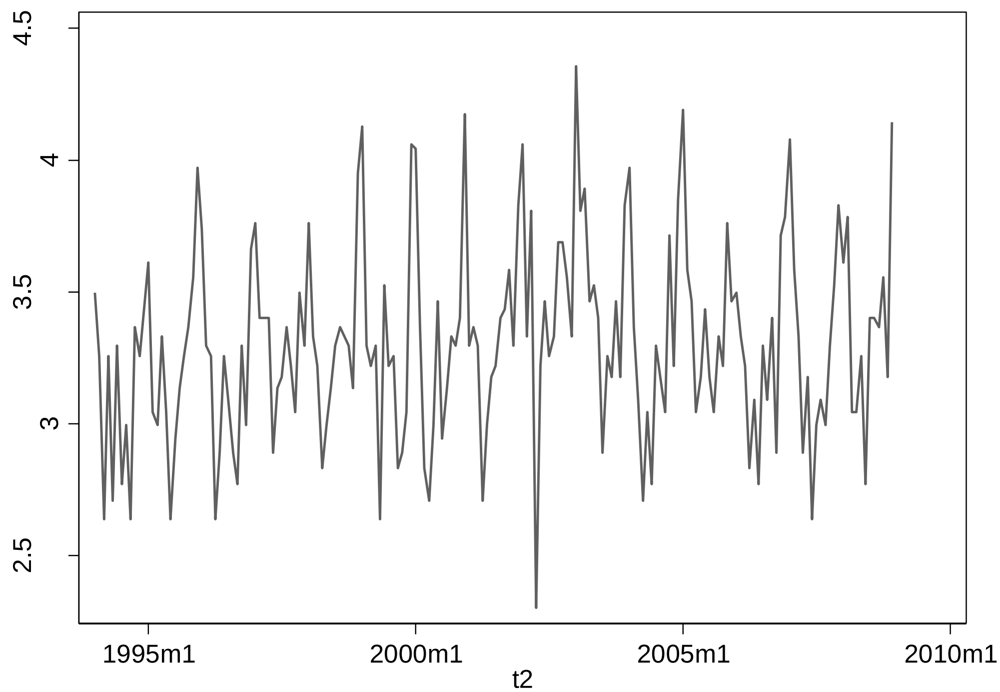



Table 5-11: Monthly average of pdo crashes and standard deviation before and after installation of cameras at 48 intersections with cameras

| Time period | # of observations (in months) | Mean of pdo crashes | Std. Dev. |
|---|---|---|---|
| *First set of 12 cameras* | | | |
| Jan. 1994 - Dec. 2002 (before) | 108 | 27.97 | 10.74 |
| Jan. 2003 - Dec. 2008 (after) | 72 | 30.68 | 12.69 |
| *Second set of 12 cameras* | | | |
| Jan. 1994 - Jul. 2003 (before) | 115 | 28.76 | 11.72 |
| Aug. 2003 - Dec. 2008 (after) | 65 | 29.58 | 11.46 |
| *Third set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2004 (before) | 126 | 28.69 | 11.68 |
| Jul. 2004 - Dec. 2008 (after) | 54 | 29.91 | 11.46 |
| *Fourth set of 12 cameras* | | | |
| Jan. 1994 - Jun. 2005 (before) | 138 | 29.06 | 11.83 |
| Jul. 2005 - Dec. 2008 (after) | 42 | 29.05 | 10.95 |

Figure 5-47 shows the log of the number of pdo crashes at all 48 camera intersections in Winnipeg for the period of January 1994 through December 2008. There does not seem to be a strong linear trend so the data will not be differenced locally. This was confirmed with a formal test (0.003; p=0.08).

Figure 5-47: Log of the number of pdo crashes in Winnipeg at 48 intersections with cameras from January 1994 through December 2008




The correlogram (see Table 5-12) reveals there is strong seasonal variation, suggesting seasonal differencing is required.

The autocorrelation and partial autocorrelation of the seasonally differenced and log-transformed pre-intervention series can also be seen in Figures 5-48 and 5-49.

Table 5-12: Autocorrelation and partial autocorrelation of the pre-intervention log transformed number of pdo crashes at 48 camera intersections

```
                                                 -1       0       1 -1       0       1
 LAG       AC       PAC       Q      Prob>Q  [Autocorrelation]  [Partial Autocor]
----------------------------------------------------------------------------------
1        0.3112   0.3112   10.749   0.0010            |--                |--
2        0.1022   0.0060    11.92   0.0026            |                  |
3       -0.1169  -0.1719   13.466   0.0037            |                 -|
4       -0.2117  -0.1507   18.584   0.0009           -|                 -|
5       -0.1434  -0.0262   20.955   0.0008           -|                  |
6       -0.0517   0.0078   21.266   0.0016            |                  |
7       -0.1849  -0.2550   25.286   0.0007           -|                --|
8       -0.2225  -0.2166   31.169   0.0001           -|                 -|
9       -0.0832   0.0167   31.999   0.0002            |                  |
10       0.1110   0.1622   33.493   0.0002            |                  |-
11       0.3115   0.1815   45.378   0.0000            |--                |-
12       0.4532   0.3360   70.792   0.0000            |---               |--
13       0.2782   0.1733    80.47   0.0000            |--                |-
14       0.0364  -0.0071   80.637   0.0000            |                  |
15      -0.0865   0.0165   81.594   0.0000            |                  |
16      -0.2628  -0.2711   90.514   0.0000          --|                --|
17      -0.1228   0.0815   92.481   0.0000            |                  |
18      -0.1036  -0.0307   93.899   0.0000            |                  |
19      -0.1473  -0.0292   96.794   0.0000           -|                  |
20      -0.1067   0.1357   98.332   0.0000            |                  |-
21      -0.0226   0.1296   98.402   0.0000            |                  |-
22      -0.0062  -0.1297   98.408   0.0000            |                 -|
23       0.3043   0.1962   111.35   0.0000            |--                |-
24       0.4143   0.3584   135.62   0.0000            |---               |--
25       0.1911  -0.0169   140.85   0.0000            |-                 |
26       0.0460   0.0411   141.16   0.0000            |                  |
27      -0.1631  -0.0506   145.06   0.0000           -|                  |
28      -0.2442  -0.0925   153.92   0.0000           -|                  |
29      -0.1492  -0.1981   157.27   0.0000           -|                 -|
30      -0.0656  -0.0633   157.92   0.0000            |                  |
31      -0.1382   0.0022   160.87   0.0000           -|                  |
32      -0.1197  -0.1031   163.11   0.0000            |                  |
33       0.0273   0.3438   163.23   0.0000            |                  |--
34       0.0579   0.0021   163.77   0.0000            |                  |
35       0.2057  -0.2558   170.65   0.0000            |-               --|
36       0.2730   0.1627   182.95   0.0000            |--                |-
37       0.1715   0.3709   187.87   0.0000            |-                 |--
38       0.0464   0.0559   188.24   0.0000            |                  |
39      -0.0982   0.1307    189.9   0.0000            |                  |-
40      -0.2042   0.1685   197.18   0.0000           -|                  |-
```

Figure 5-48: Autocorrelation of pre-intervention log-transformed, seasonally differenced pdo crashes

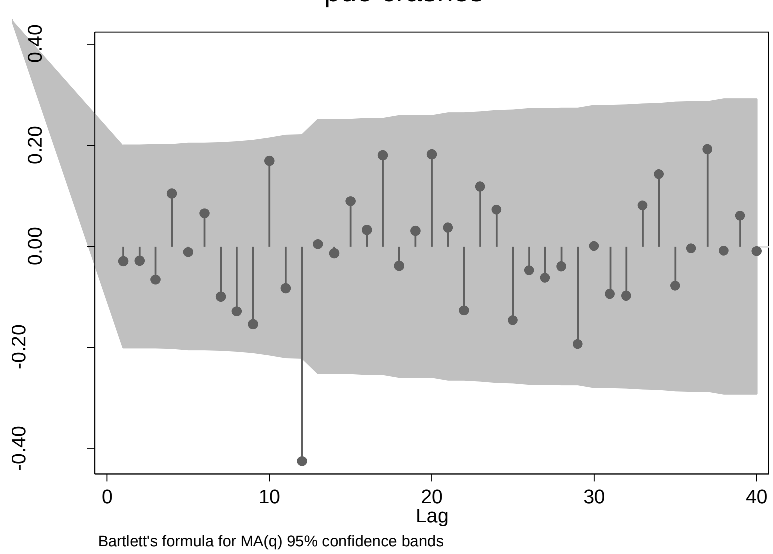
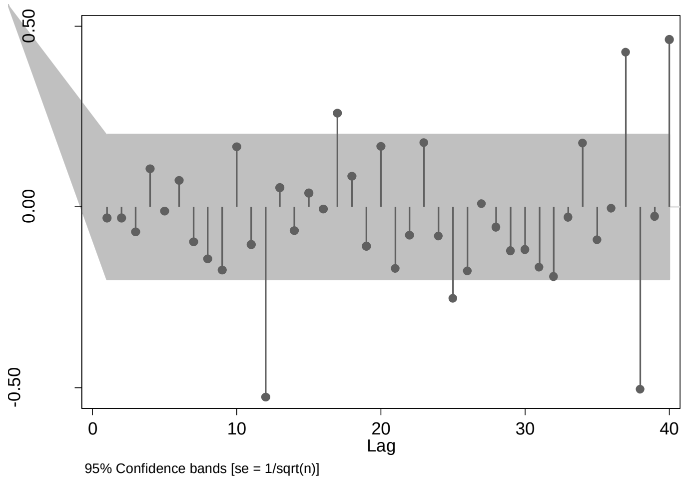


Figure 5-49: Partial autocorrelation of pre-intervention log-transformed, seasonally differenced pdo crashes




Several models that were considered viable based on the information from the autocorrelation and partial autocorrelation plots were compared to one another using AIC and BIC as well as the significant values of the ARIMA structure. The following model was found with the lowest AIC and BIC values (46.52 and 59.34 respectively), as well as significant ARMA terms that are within the bounds of stationarity and invertibility. Note that the AR term associated with the first lag is not significant. A model containing only the seasonal AR term was studied as well and the results are consistent across both models (because it is reasonable to assume that the ARIMA process for both types of crashes, i.e., injury and pdo crashes, is comparable given that these crashes are caused by the same population, we present and discuss the results from the process with both AR terms).

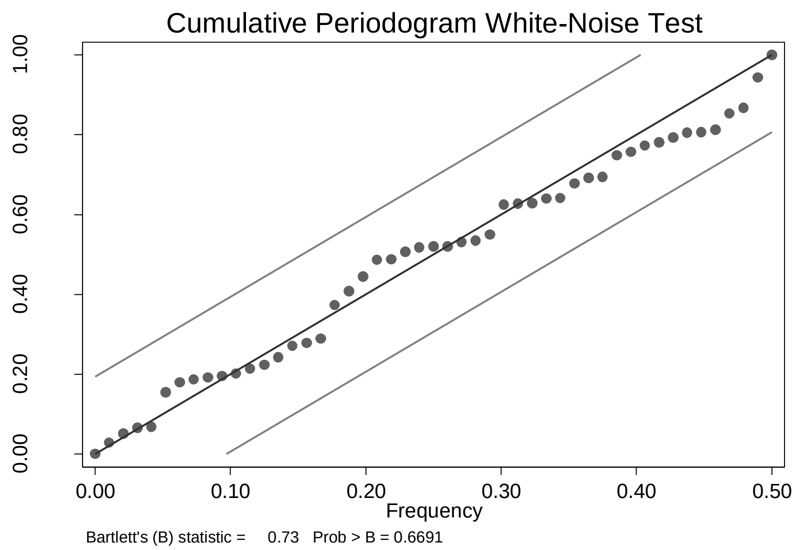
```
ARIMA regression

      Sample:  1995m1 - 2002m12                        Number of obs      =        96
                                                       Wald chi2(4)       =   1859.75
      Log pseudolikelihood = -18.26156                 Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
                   |              Semirobust
       S12.lnpdo48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnpdo48      |
            pulse1 |
              S12. |   .4573975   .2792174     1.64   0.101    -.0898585    1.004654
                   |
            pulse2 |
              S12. |  -.4274538   .0625447    -6.83   0.000    -.5500392   -.3048685
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |    .029983   .0843361     0.36   0.722    -.1353128    .1952788
              L12. |  -.5202914   .1001756    -5.19   0.000     -.716632   -.3239508
      -------------+----------------------------------------------------------------
            /sigma |   .2869405   .0204208    14.05   0.000     .2469164    .3269646
      ------------------------------------------------------------------------------
```

A white noise test of the residuals of this final model confirms the residuals are indeed distributed according to a white noise pattern. According to Bartlett's statistic the Null hypothesis of white noise can not be rejected (0.73; p=0.67) and the dots in the figure below are all within the confidence bounds. Also, Portmanteau's test does not reject the Null hypothesis of white noise (39.95; p=0.47).

Figure 5-50: Cumulative periodogram white noise test and Bartlett's statistic of the residuals of the final pre-intervention model




The following graphs also show that the residuals of this model are normally distributed.

Figure 5-51: Standardized normal probability plot of the residuals of the final pre-intervention model

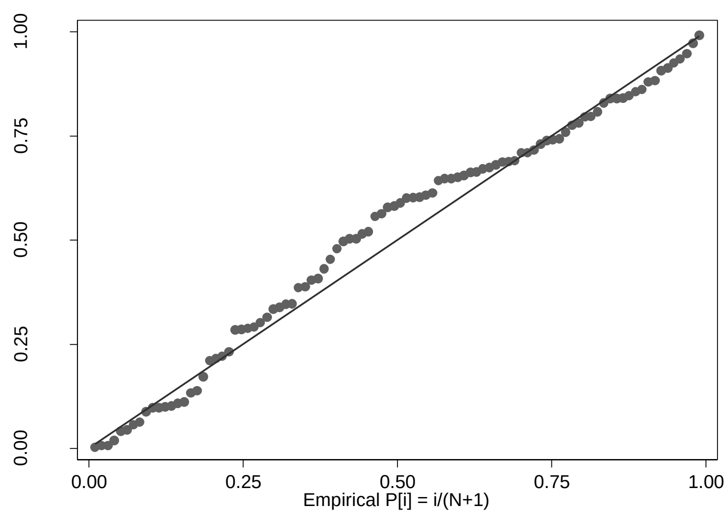
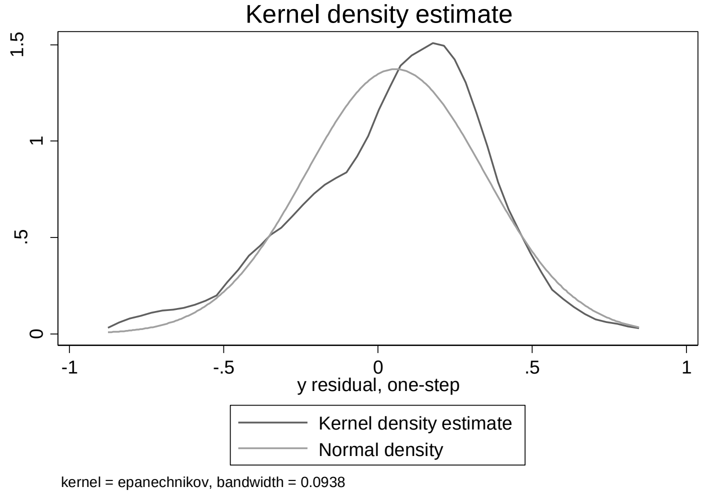


Figure 5-52: Normal density plot of the residuals of the final pre-intervention model




Finally, Figure 5-53 shows how the final model fits with the actual data of the pre-intervention series. Based on these one-step-ahead predictions, the model seems to fit the data reasonably well.

Figure 5-53: log-transformed number of pdo crashes and one-step-ahead predictions according to final model for 48 intersections with cameras, pre-intervention

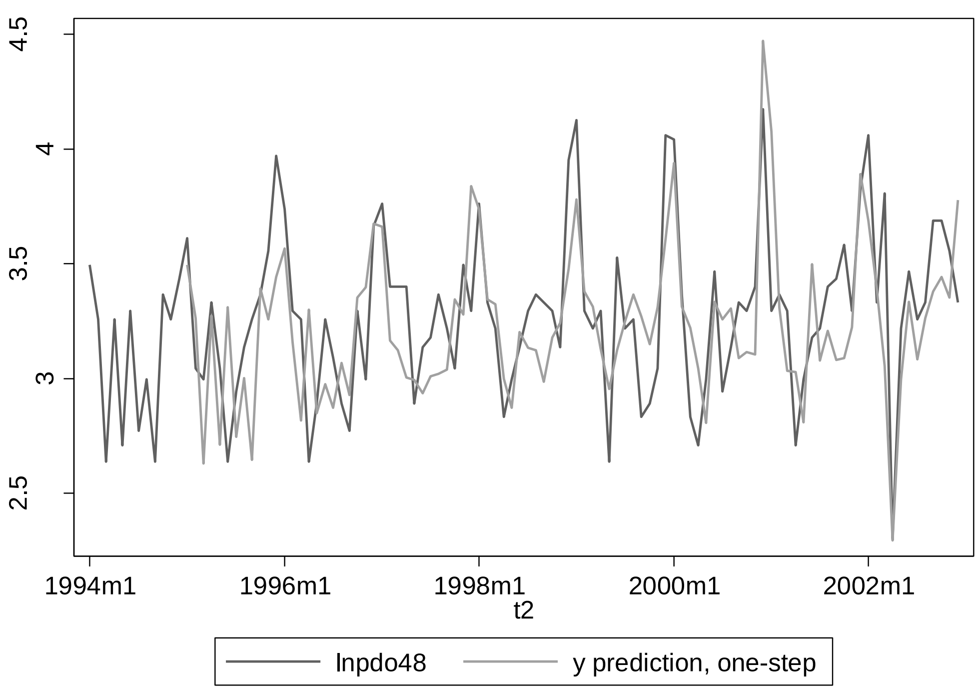
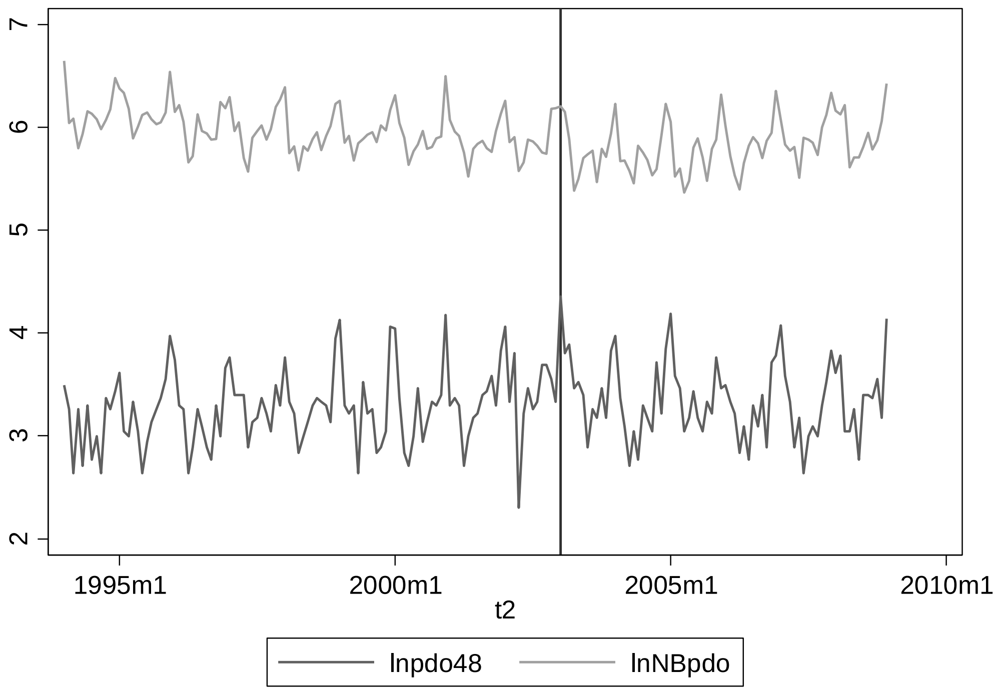


Figure 5-54 contains the experimental group with pdo crashes from Winnipeg and the control group with pdo crashes from New Brunswick.

Figure 5-54: log-transformed number of pdo crashes in the experimental group (Winnipeg, lnpdo48) and the control group (New Brunswick, lnNBpdo)




As can be seen in the model with the dummy variables and control group data, the installation of the first set of cameras was associated with a significant 29.18% increase in pdo crashes at camera intersections (0.256; p=0.024) but this was followed by a significant 35.40% decrease (-0.437; p=0.000), another significant 20.08% increase (0.183; p=0.021) and another significant 13.50% decrease (albeit significant at the 10% level; -0.145; p=0.096). As mentioned, results for a model excluding the non-significant AR term associated with the first lag were studied. These results were consistent.

When only considering the strongest evidence (significant at the 5% level), the net effect is virtually zero: a 0.20% increase in pdo crashes at camera intersections ($\omega$=0.256-0.437+0.183 using the formula ($100 \text{ x } (e^{\omega} - 1)$)). When also considering the last decrease (significant at the 10% level), the net effect is a 13.32% decrease in pdo crashes at camera intersections ($\omega$=0.256-0.437+0.183-0.145).

```
ARIMA regression with control group, AR 1 12

      Sample:  1995m1 - 2008m12                        Number of obs      =       168
                                                       Wald chi2(10)      =     88.79
      Log pseudolikelihood = -26.42533                 Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
                   |                 Semirobust
        S12.lnpdo48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnpdo48      |
            pulse1 |
              S12. |   .4179077   .2454431     1.70   0.089    -.0631519    .8989674
                   |
            pulse2 |
              S12. |  -.5498627   .1906564    -2.88   0.004    -.9235424   -.1761829
                   |
            pulse3 |
              S12. |   .2234463   .1891661     1.18   0.238    -.1473124    .5942049
                   |
           lnNBpdo |
              S12. |  -.0004921   .1343156    -0.00   0.997    -.2637458    .2627615
                   |
            dummy1 |
              S12. |   .2555681    .113004     2.26   0.024     .0340843    .4770519
                   |
            dummy2 |
              S12. |  -.4368214   .1187837    -3.68   0.000    -.6696333   -.2040096
                   |
            dummy3 |
              S12. |   .1829959   .0792962     2.31   0.021     .0275781    .3384136
                   |
            dummy4 |
              S12. |  -.1453106   .0871792    -1.67   0.096    -.3161787    .0255574
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |  -.0082605   .0670972    -0.12   0.902    -.1397687    .1232477
              L12. |  -.4780656   .0814624    -5.87   0.000     -.637729   -.3184022
      -------------+----------------------------------------------------------------
            /sigma |   .2805687    .013934    20.14   0.000     .2532587    .3078788
      ------------------------------------------------------------------------------
```

### 5.3.4 Speeding in Winnipeg excluding 48 camera intersections

The analyses of speeding related crashes were replicated in this section with data from Winnipeg at intersections, excluding the 48 camera intersections.

**Injury crashes in Winnipeg.** Figure 5-55 shows the number of injury crashes at all intersections in Winnipeg where no photo enforcement cameras are used for the period of January 1994 through December 2008. As can be seen in this figure, there are several outliers and the variance of this crash series changes over time so the data will be log-transformed and further analyses will be conducted on these transformed data. It is also apparent from this figure that the pattern at the outset of this series differs from the pattern passed March 1996: before this point there appears to be a decreasing trend with extreme outliers whereas the series is flatter and better behaved after this point. For this reason, data from before March 1996 will not be used in this analysis, not to build the pre-intervention model, nor to test the impact of the dummy variables associated with the installation of cameras.

Figure 5-55: Number of injury crashes in Winnipeg at intersections without cameras from January 1994 through December 2008

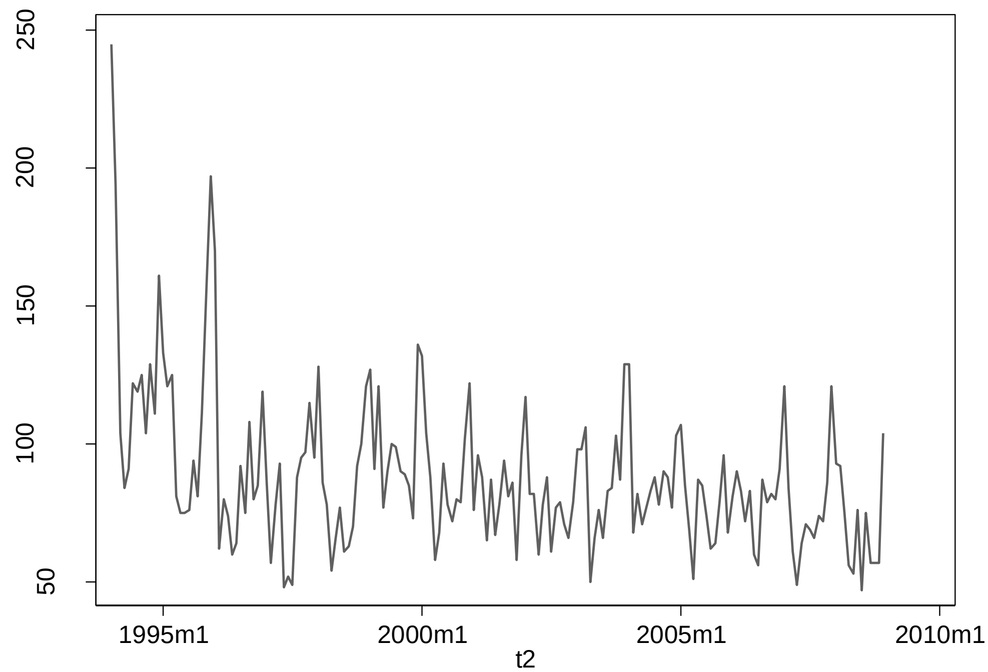



Table 5-13 reveals that the monthly average of injury crashes after installation of each set of cameras is lower than before installation.

Table 5-13: Monthly average of injury crashes and standard deviation before and after installation of cameras in Winnipeg, excluding camera intersections (note that data from before March 1996 are not included)

| Time period | # of observations (in months) | Mean of injury crashes | Std. Dev. |
|---|---|---|---|
| *First set of 12 cameras* | | | |
| Mar. 1996 - Dec. 2002 (before) | 82 | 84.78 | 19.89 |
| Jan. 2003 - Dec. 2008 (after) | 72 | 79.60 | 18.24 |
| *Second set of 12 cameras* | | | |
| Mar. 1996 - Jul. 2003 (before) | 89 | 84.40 | 19.89 |
| Aug. 2003 - Dec. 2008 (after) | 65 | 79.55 | 18.10 |
| *Third set of 12 cameras* | | | |
| Mar. 1996 - Jun. 2004 (before) | 100 | 85.08 | 20.00 |
| Jul. 2004 - Dec. 2008 (after) | 54 | 77.31 | 16.79 |
| *Fourth set of 12 cameras* | | | |
| Mar. 1996 - Jun. 2005 (before) | 112 | 84.96 | 19.45 |
| Jul. 2005 - Dec. 2008 (after) | 42 | 75.40 | 17.03 |

Figure 5-56 shows the log of the number of injury crashes in Winnipeg at intersections where no photo enforcement cameras are installed for the period of March 1996 through December 2008. As can be seen, there is no apparent strong up- or downward trend in the pre-intervention series (March 1996 through December 2002), which suggests the data do not have to be differenced locally before analyzing them. This was formally tested and confirmed (-0.002; p=0.180).

Also, as can be seen in the correlogram (see Table 5-14), there is seasonal variation, suggesting seasonal differencing is required.

Figure 5-56: Log of the number of injury crashes in Winnipeg at intersections without cameras from March 1996 through December 2008

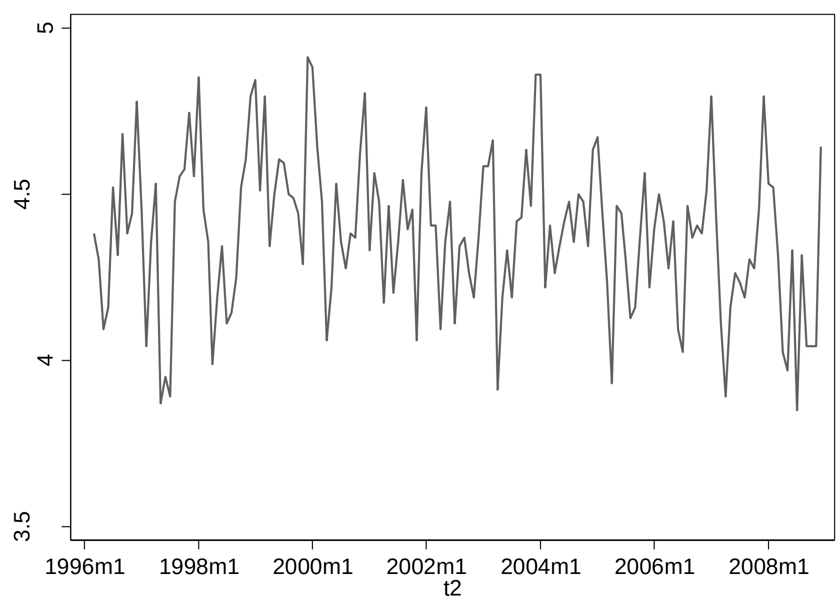


Table 5-14: Autocorrelation and partial autocorrelation of the pre-intervention log transformed number of injury crashes in Winnipeg at intersections without cameras

-1 0 1 -1 0 1

| LAG | AC | PAC | Q | Prob>Q | [Autocorrelation] | [Partial Autocor] |
|---|---|---|---|---|---|---|
| 1 | 0.3828 | 0.3829 | 12.458 | 0.0004 | \|--- | \|--- |
| 2 | 0.1380 | -0.0089 | 14.099 | 0.0009 | \|- | \| |
| 3 | 0.0494 | 0.0005 | 14.311 | 0.0025 | \| | \| |
| 4 | -0.1069 | -0.1482 | 15.321 | 0.0041 | \| | -\| |
| 5 | -0.0491 | 0.0463 | 15.537 | 0.0083 | \| | \| |
| 6 | -0.2587 | -0.2983 | 21.601 | 0.0014 | --\| | --\| |
| 7 | -0.2902 | -0.1144 | 29.337 | 0.0001 | --\| | \| |
| 8 | -0.2306 | -0.1199 | 34.288 | 0.0000 | -\| | \| |
| 9 | -0.0048 | 0.2106 | 34.29 | 0.0001 | \| | \|- |
| 10 | 0.0474 | -0.0903 | 34.505 | 0.0002 | \| | \| |
| 11 | 0.1792 | 0.2464 | 37.62 | 0.0001 | \|- | \|- |
| 12 | 0.3307 | 0.1810 | 48.383 | 0.0000 | \|-- | \|- |
| 13 | 0.3314 | 0.2233 | 59.35 | 0.0000 | \|-- | \|- |
| 14 | 0.3205 | -0.0010 | 69.757 | 0.0000 | \|-- | \| |
| 15 | 0.0545 | -0.1442 | 70.062 | 0.0000 | \| | -\| |
| 16 | -0.1206 | -0.1957 | 71.579 | 0.0000 | \| | -\| |
| 17 | -0.2110 | -0.1326 | 76.298 | 0.0000 | -\| | -\| |
| 18 | -0.1288 | 0.1549 | 78.083 | 0.0000 | -\| | \|- |
| 19 | -0.1574 | -0.0742 | 80.791 | 0.0000 | -\| | \| |
| 20 | -0.2294 | -0.0296 | 86.637 | 0.0000 | -\| | \| |
| 21 | -0.1255 | 0.0684 | 88.415 | 0.0000 | -\| | \| |
| 22 | -0.1161 | -0.0693 | 89.963 | 0.0000 | \| | \| |
| 23 | 0.1199 | 0.0004 | 91.641 | 0.0000 | \| | \| |
| 24 | 0.2276 | 0.0940 | 97.791 | 0.0000 | \|- | \| |
| 25 | 0.1277 | -0.1695 | 99.762 | 0.0000 | \|- | -\| |
| 26 | 0.0929 | -0.1646 | 100.82 | 0.0000 | \| | -\| |
| 27 | 0.0320 | 0.0401 | 100.95 | 0.0000 | \| | \| |
| 28 | -0.0529 | -0.1813 | 101.31 | 0.0000 | \| | -\| |
| 29 | -0.1121 | -0.0194 | 102.94 | 0.0000 | \| | \| |
| 30 | -0.1517 | -0.1703 | 105.99 | 0.0000 | -\| | -\| |
| 31 | -0.2735 | -0.1457 | 116.09 | 0.0000 | --\| | -\| |
| 32 | -0.1914 | -0.2048 | 121.14 | 0.0000 | -\| | -\| |
| 33 | -0.0452 | 0.1815 | 121.42 | 0.0000 | \| | \|- |
| 34 | -0.0516 | -0.0113 | 121.81 | 0.0000 | \| | \| |
| 35 | 0.0038 | -0.0449 | 121.81 | 0.0000 | \| | \| |
| 36 | 0.0824 | 0.2456 | 122.83 | 0.0000 | \| | \|- |
| 37 | 0.0532 | -0.1121 | 123.26 | 0.0000 | \| | \| |
| 38 | 0.0917 | 0.0502 | 124.57 | 0.0000 | \| | \| |
| 39 | 0.0445 | -0.0021 | 124.89 | 0.0000 | \| | \| |

The autocorrelation and partial autocorrelation of the log transformed, seasonally differenced pre-intervention series can also be seen in Figures 5-57 and 5-58.

Figure 5-57: Autocorrelation of pre-intervention log-transformed, seasonally differenced injury crashes in Winnipeg at intersections without cameras

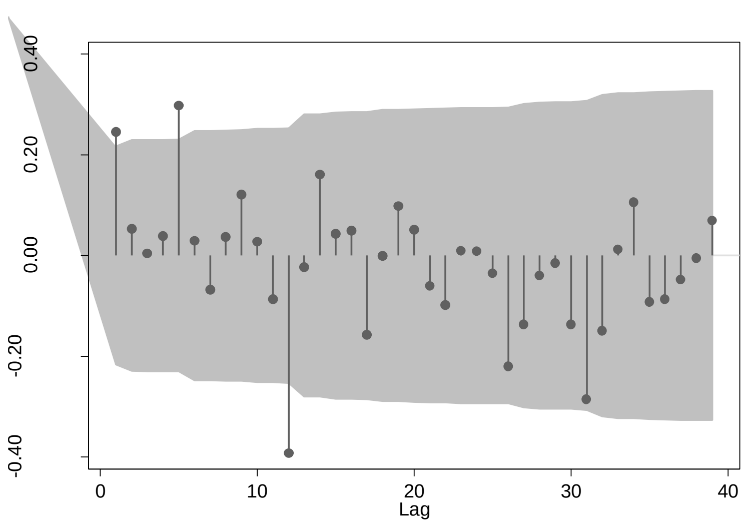
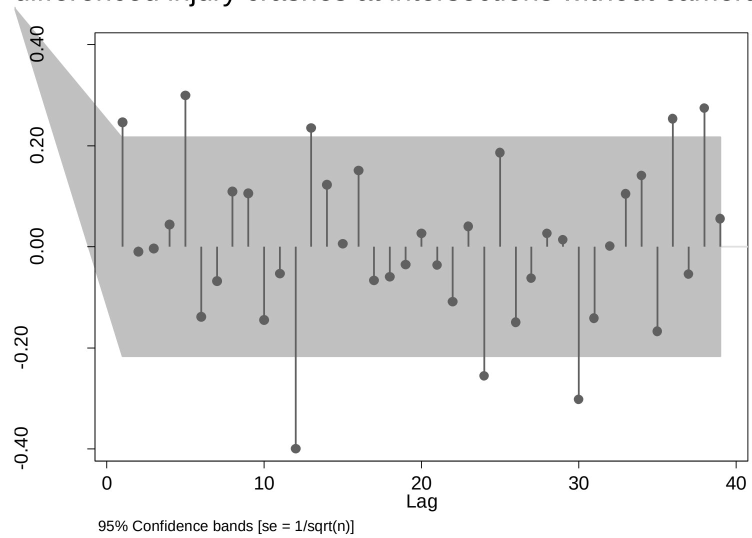


Figure 5-58: Partial autocorrelation of pre-intervention log-transformed, seasonally differenced injury crashes at intersections without cameras




Several models that were considered viable based on the information from the autocorrelation and partial autocorrelation plots were compared to one another using AIC and BIC as well as the significant values of the ARIMA structure. The following model was found with the lowest AIC and BIC values (11.21 and 18.43 respectively), as well as significant ARMA terms that are within the bounds of stationarity and invertibility. It warrants mentioning that two alternative models were found that also fit the data well, one with only a seasonal AR term and one with two MA terms, associated with the first and twelfth lag. The results were consistent across all three models; only results from the AR model with two terms are presented.

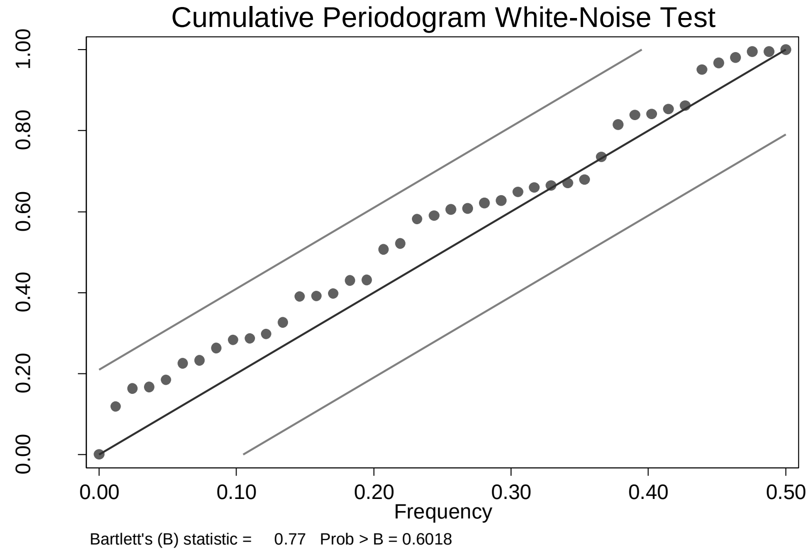
```
ARIMA regression

      Sample:  1996m3 - 2002m12                       Number of obs      =        82
                                                      Wald chi2(2)       =     29.23
      Log pseudolikelihood = -2.603691                Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |              Semirobust
      lninjuryW~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .219139   .0953511     2.30   0.022     .0322542    .4060237
              L12. |  -.4430715   .0974119    -4.55   0.000    -.6339954   -.2521476
      -------------+----------------------------------------------------------------
            /sigma |   .2454349   .0172544    14.22   0.000      .211617    .2792528
      ------------------------------------------------------------------------------
```

A white noise test of the residuals of this final model confirms the residuals are indeed distributed according to a white noise pattern. According to Bartlett's statistic the Null hypothesis of white noise can not be rejected (0.77; p=0.60) and the dots in the figure below are all within the confidence bounds. Also, Portmanteau's test does not reject the Null hypothesis of white noise (51.53; p=0.09).

Figure 5-59: Cumulative periodogram white noise test and Bartlett's statistic of the residuals of the final pre-intervention model




The following graphs also show that the residuals of this model are normally distributed.

Figure 5-60: Standardized normal probability plot of the residuals of the final pre-intervention model

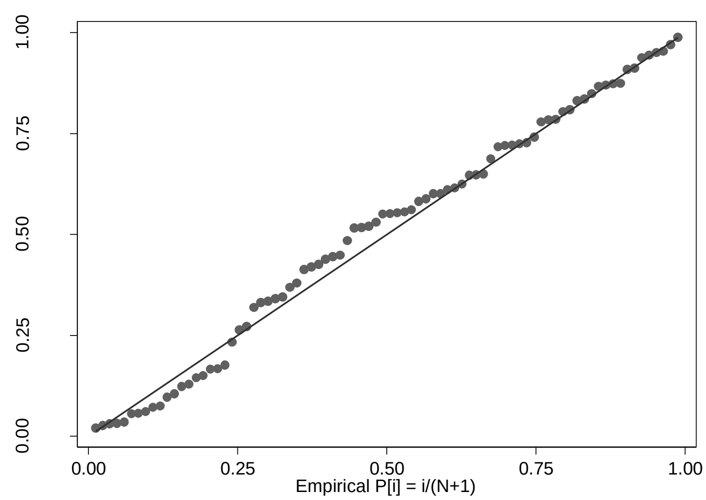
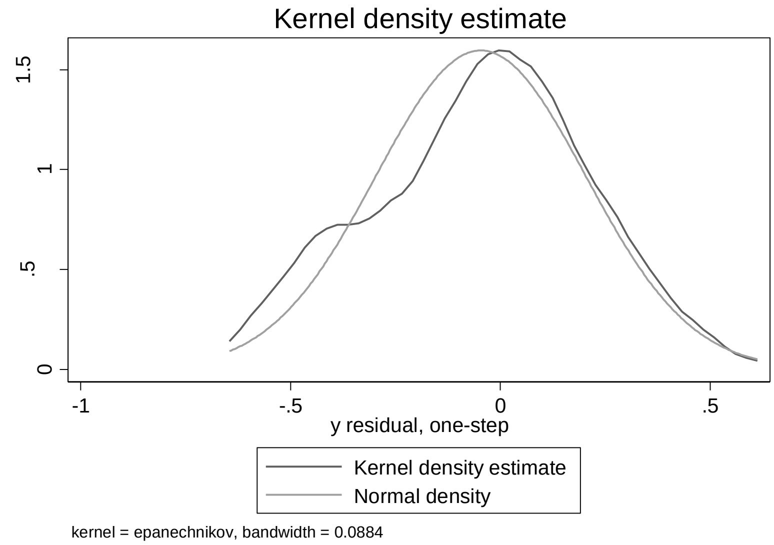


Figure 5-61: Normal density plot of the residuals of the final pre-intervention model




Finally, Figure 5-62 shows how the final model fits with the actual data of the pre-intervention series. Based on these one-step-ahead predictions, the model seems to fit the data reasonably well.

Figure 5-62: log-transformed number of injury crashes and one-step-ahead predictions according to final model for Winnipeg at intersections without cameras, pre-intervention

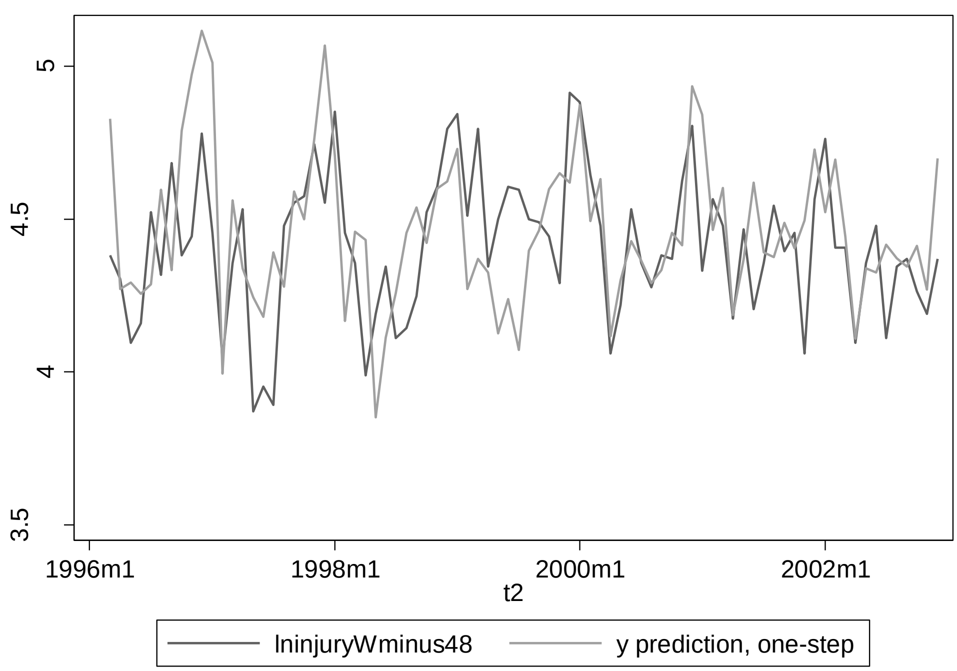
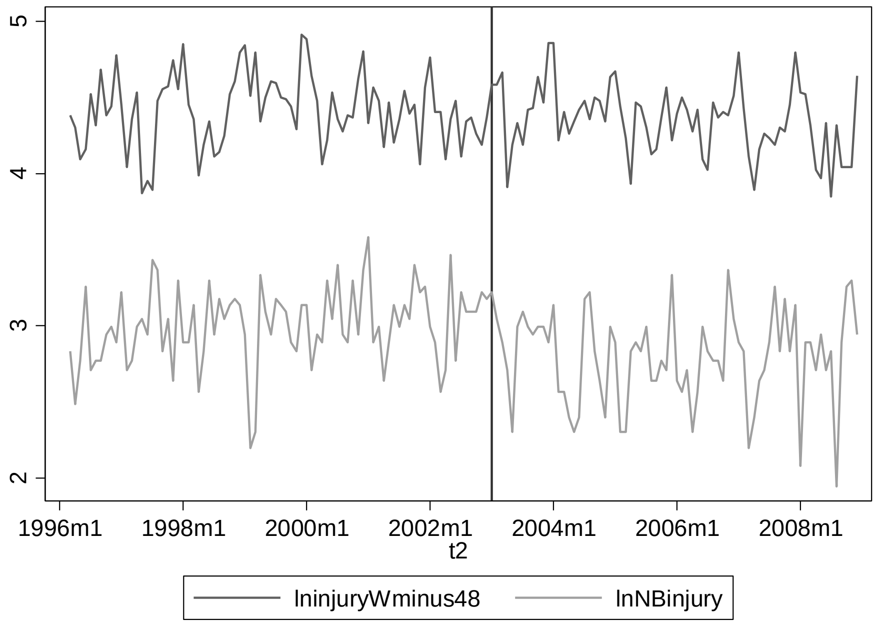


Figure 5-63 contains the experimental group with injury crashes from Winnipeg, excluding camera intersections and the control group with injury crashes from New Brunswick.

Figure 5-63: log-transformed number of injury crashes in the experimental group (Winnipeg, lninjuryWminus48) and the control group (New Brunswick, lnNBinjury)




As can be seen in the model with the dummy variables and control group data, there were no significant effects. Note that the same conclusions can be drawn using the alternative models that also fit the data well. This suggests there were no spill-over effects of the photo enforcement cameras on injury crashes at intersections in Winnipeg without such cameras.

```
ARIMA regression

      Sample:  1996m3 - 2008m12                       Number of obs      =       154
                                                      Wald chi2(7)       =     74.87
      Log pseudolikelihood =  14.61693                Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |                Semirobust
      lninjuryW~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lninjuryW~48 |
        lnNBinjury |
              S12. |  -.1361365   .0579788    -2.35   0.019    -.2497729   -.0225001
                   |
            dummy1 |
              S12. |   .0155513   .0712564     0.22   0.827    -.1241086    .1552112
                   |
            dummy2 |
              S12. |   .0594791     .087933    0.68   0.499    -.1128664    .2318247
                   |
            dummy3 |
              S12. |  -.0232061   .0722877    -0.32   0.748    -.1648873    .1184751
                   |
            dummy4 |
              S12. |  -.1067609   .0663833    -1.61   0.108    -.2368696    .0233479
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .2020347   .0723128     2.79   0.005     .0603043    .3437652
              L12. |  -.4952567   .0710145    -6.97   0.000    -.6344426   -.3560709
      -------------+----------------------------------------------------------------
            /sigma |    .217458   .0111178    19.56   0.000     .1956675    .2392485
      ------------------------------------------------------------------------------
```

**Pdo crashes in Winnipeg.** Figure 5-64 shows the number of pdo crashes at all intersections in Winnipeg where no photo enforcement cameras are used for the period of January 1994 through December 2008. As can be seen in this figure, there are several outliers and the variance of this crash series changes over time so the data will be log-transformed and further analyses will be conducted on these transformed data. It is also apparent from this figure that the pattern at the outset of this series differs from the pattern passed January 2000. For this reason, data from before January 2000 will not be used in this analysis, not to build the pre-intervention model, nor to test the impact of the dummy variables associated with the installation of cameras.

Table 5-15 reveals that the monthly average of pdo crashes after installation of each set of cameras is higher than before installation. However, the difference is not great and becomes gradually smaller for later installations of cameras.

Figure 5-64: Number of pdo crashes in Winnipeg at intersections without cameras from January 1994 through December 2008

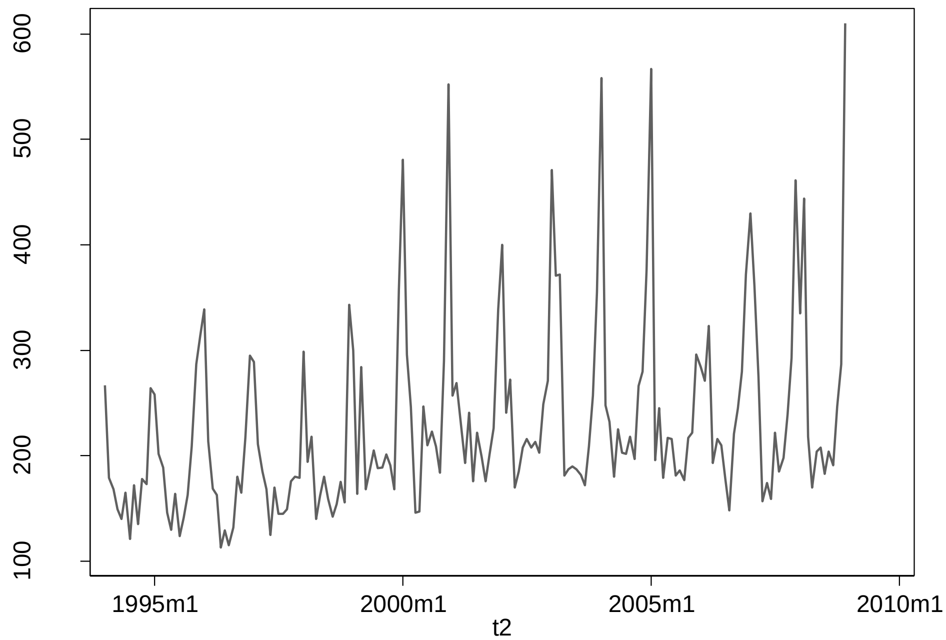



Table 5-15: Monthly average of pdo crashes and standard deviation before and after installation of cameras in Winnipeg (note that data from before January 2000 are not included)

| Time period | # of observations (in months) | Mean of pdo crashes | Std. Dev. |
|---|---|---|---|
| *First set of 12 cameras* | | | |
| Jan. 2000 - Dec. 2002 (before) | 36 | 244.44 | 84.27 |
| Jan. 2003 - Dec. 2008 (after) | 72 | 258.53 | 101.57 |
| *Second set of 12 cameras* | | | |
| Jan. 2000 - Jul. 2003 (before) | 43 | 250.21 | 90.54 |
| Aug. 2003 - Dec. 2008 (after) | 65 | 256.23 | 100.05 |
| *Third set of 12 cameras* | | | |
| Jan. 2000 - Jun. 2004 (before) | 54 | 251.48 | 94.23 |
| Jul. 2004 - Dec. 2008 (after) | 54 | 256.19 | 98.54 |
| *Fourth set of 12 cameras* | | | |
| Jan. 2000 - Jun. 2005 (before) | 66 | 253.62 | 96.38 |
| Jul. 2005 - Dec. 2008 (after) | 42 | 254.17 | 96.54 |

Figure 5-65 shows the log of the number of pdo crashes in Winnipeg at intersections where no photo enforcement cameras are used for the period of January 2000 through December 2008. As can be seen, there is no apparent strong up- or downward trend in the pre-intervention series (January 2000 through December 2002), which suggests the data do not have to be differenced locally before analyzing them. This was confirmed with a formal test (0.002; p=0.167). There are still outliers, despite the log-transformation. Pulse variables will be used to control the impact of these outliers.

Also, as can be seen in the correlogram (see Table 5-16), there is seasonal variation, suggesting seasonal differencing is required.

Figure 5-65: Log of the number of pdo crashes in Winnipeg at intersections without cameras from January 2000 through December 2008

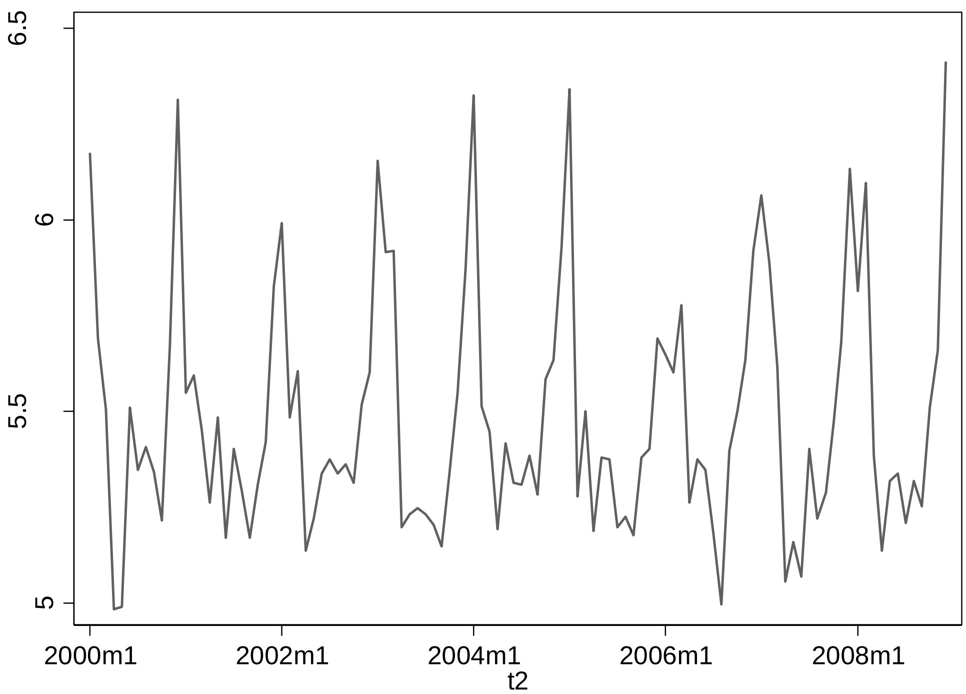



Table 5-16: Autocorrelation and partial autocorrelation of the pre-intervention log transformed number of pdo crashes in Winnipeg at intersections without cameras

```
                                             -1       0       1 -1       0       1
LAG       AC        PAC       Q      Prob>Q  [Autocorrelation]  [Partial Autocor]
-----------------------------------------------------------------------------------
1        0.3553    0.3570   4.9345   0.0263           |--                |--
2        0.0065   -0.1443   4.9362   0.0847           |                 -|
3       -0.2242   -0.2112   7.0207   0.0712          -|                 -|
4       -0.3283   -0.2626   11.628   0.0203         --|                --|
5       -0.0577    0.1528   11.774   0.0380           |                  |-
6       -0.1605   -0.2674   12.949   0.0439          -|                --|
7       -0.3257   -0.4295   17.953   0.0122         --|               ---|
8       -0.2654   -0.2704   21.395   0.0062         --|                --|
9       -0.1929   -0.3501    23.28   0.0056          -|                --|
10       0.1228   -0.2347   24.074   0.0074           |                 -|
11       0.3884   -0.0786   32.329   0.0007           |---               |
12       0.2861    0.0540   36.995   0.0002           |--                |
13       0.3280    0.2097   43.392   0.0000           |--                |-
14       0.0729    0.0236   43.723   0.0001           |                  |
15      -0.0516    0.0409   43.897   0.0001           |                  |
16      -0.0616    0.1499   44.156   0.0002           |                  |-
```

The autocorrelation and partial autocorrelation of the log transformed, seasonally differenced pre-intervention series can also be seen in Figures 5-66 and 5-67.

Figure 5-66: Autocorrelation of pre-intervention log-transformed, seasonally differenced pdo crashes in Winnipeg at intersections without cameras

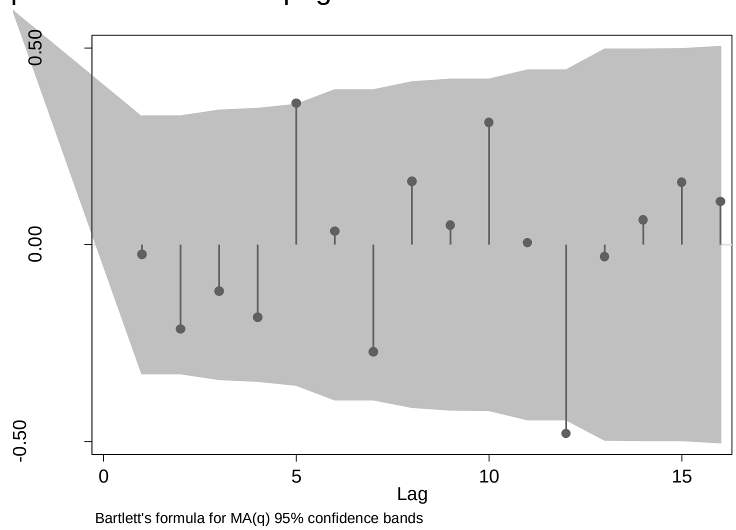
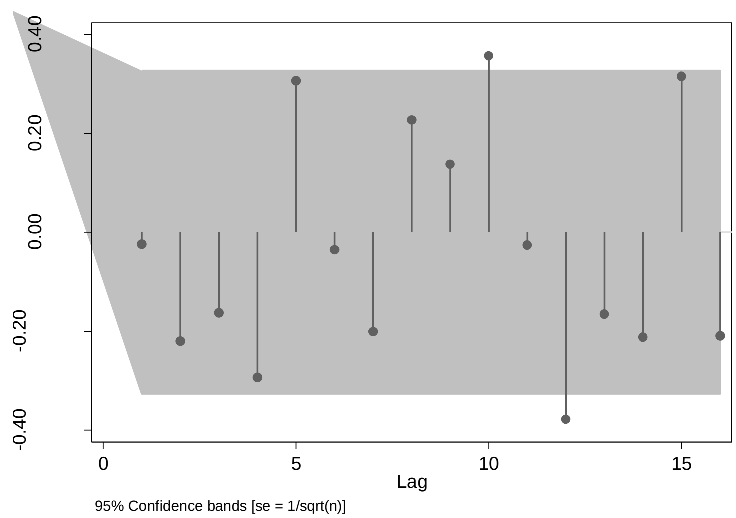



Figure 5-67: Partial autocorrelation of pre-intervention log-transformed, seasonally differenced pdo crashes at intersections without cameras




Several models that were considered viable based on the information from the autocorrelation and partial autocorrelation plots were compared to one another using AIC and BIC as well as the significant values of the ARIMA structure. The following model was found with the lowest AIC and BIC values (-8.99 and -1.07 respectively), as well as significant ARMA terms that are within the bounds of stationarity and invertibility. Comparable to the model for injuries in Winnipeg, an alternative model that only contains the seasonal AR term also fits the data well. For pdo crashes too the results were consistent across both models so only results from the AR model with two terms (AR1 and AR12) are presented.

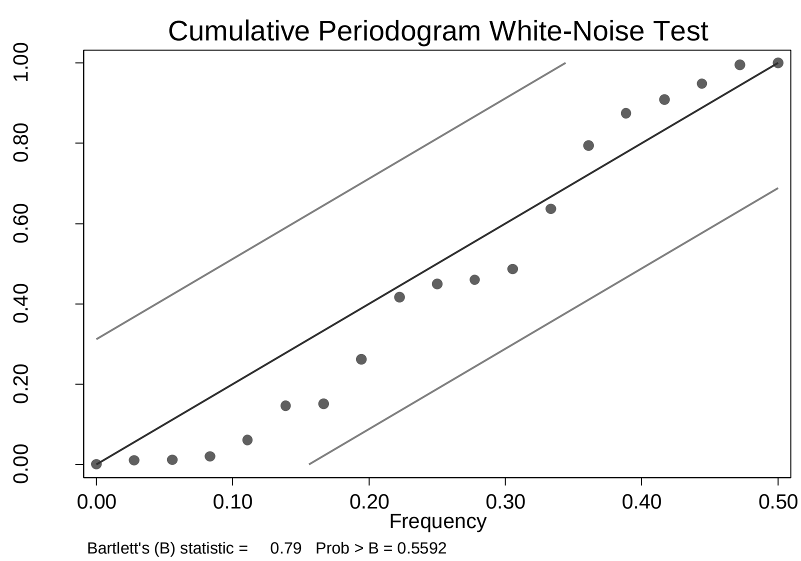
```
ARIMA regression

      Sample:  2000m1 - 2002m12                       Number of obs      =        36
                                                      Wald chi2(4)       =     65.30
      Log pseudolikelihood =  9.496063                Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |             Semirobust
      lnpdowmin~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnpdowmin~48 |
            pulse1 |
              S12. |   .3217612   .2527049     1.27   0.203    -.1735313    .8170537
                   |
            pulse2 |
              S12. |   .6180795   .1248151     4.95   0.000     .3734464    .8627126
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |  -.0660773   .1192766    -0.55   0.580    -.2998551    .1677005
              L12. |  -.7034067   .1903329    -3.70   0.000    -1.076452    -.330361
      -------------+----------------------------------------------------------------
            /sigma |   .1656181   .0207624     7.98   0.000     .1249246    .2063116
      ------------------------------------------------------------------------------
```

A white noise test of the residuals of this final model confirms the residuals are indeed distributed according to a white noise pattern. According to Bartlett's statistic the Null hypothesis of white noise can not be rejected (0.79; p=0.56) and the dots in the figure below are all within the confidence bounds. Also, Portmanteau's test does not reject the Null hypothesis of white noise (19.04; p=0.27).

Figure 5-68: Cumulative periodogram white noise test and Bartlett's statistic of the residuals of the final pre-intervention model



The following graphs show that the residuals of this model are normally distributed.

Figure 5-69: Standardized normal probability plot of the residuals of the final pre-intervention model

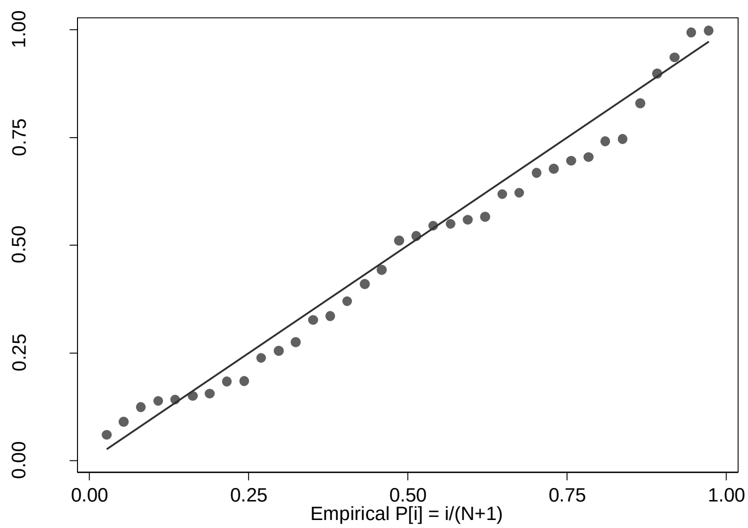
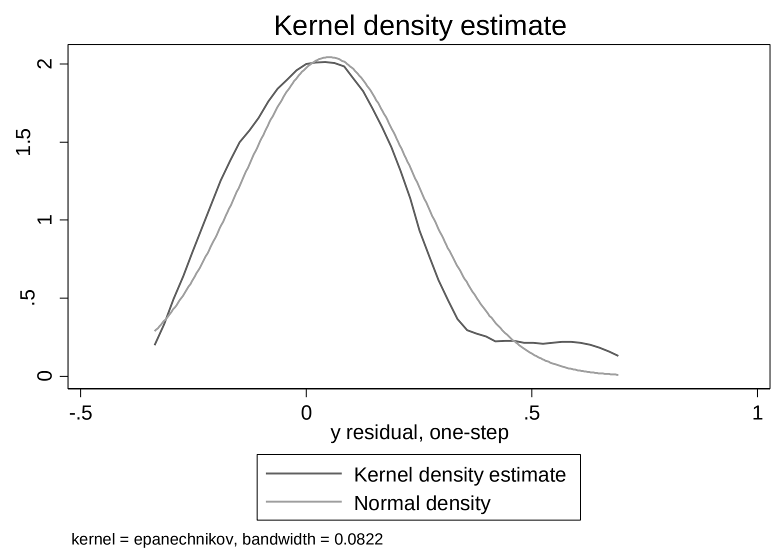



Figure 5-70: Normal density plot of the residuals of the final pre-intervention model




Finally, Figure 5-71 shows how the final model fits with the actual data of the pre-intervention series. Based on these one-step-ahead predictions, the model seems to fit the data reasonably well.

Figure 5-71: log-transformed number of pdo crashes and one-step-ahead predictions according to final model for Winnipeg at intersections without cameras, pre-intervention

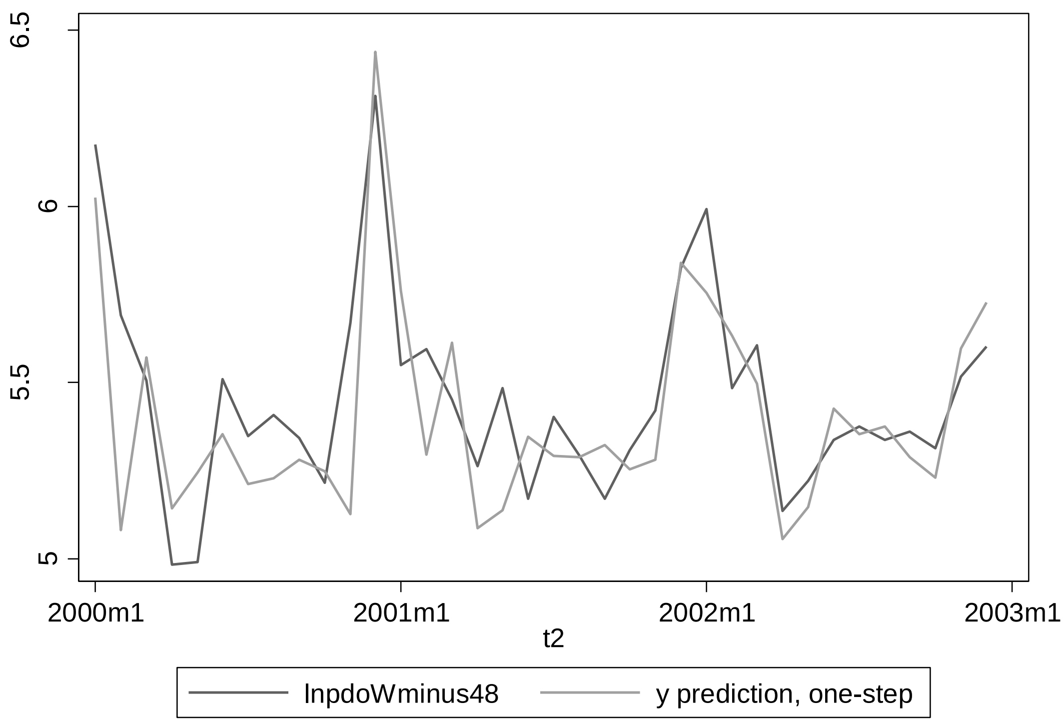
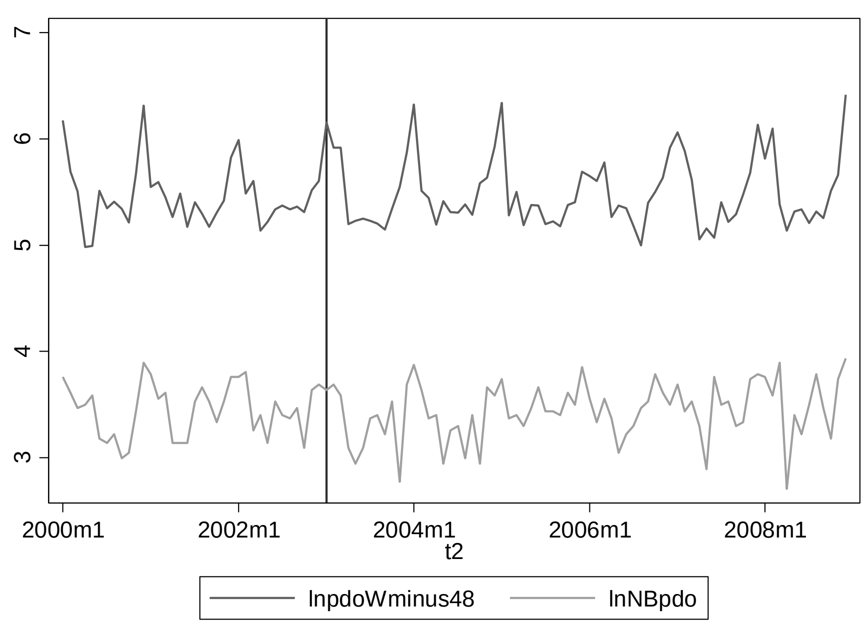



Figure 5-72 contains the experimental group with pdo crashes from Winnipeg and the control group with pdo crashes from New Brunswick.

Figure 5-72: log-transformed number of pdo crashes in the experimental group (Winnipeg, lnpdoWminus48) and the control group (New Brunswick, lnNBpdo)



As can be seen in the model with the dummy variables and control group data, there was a significant (at the 10%-level) 17.94% increase (0.165; p=0.057) followed by a 13.50% decrease (-0.145; p=0.059) associated with the use of the first set and second set of cameras. The net effect is nominal: a 2.02% increase. None of the other dummy variables are significant. This suggests there were no spill-over effects of the photo enforcement cameras on pdo crashes at intersections without such cameras. The same conclusions can be drawn from a model without control group data or a model with control group data and only a seasonal AR term.

```
ARIMA regression

      Sample:  2000m1 - 2008m12                       Number of obs      =       108
                                                      Wald chi2(12)      =  2.21e+09
      Log pseudolikelihood =  31.25512                Prob > chi2        =    0.0000

      ------------------------------------------------------------------------------
      S12.         |              Semirobust
      lnpdowmin~48 |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
      -------------+----------------------------------------------------------------
      lnpdowmin~48 |
            pulse1 |
              S12. |   .3576541   .2034376     1.76   0.079    -.0410763    .7563845
                   |
            pulse2 |
              S12. |   .5397164   .1499662     3.60   0.000     .2457879    .8336448
                   |
            pulse3 |
              S12. |   .3994069   .1407098     2.84   0.005     .1236207    .6751932
                   |
            pulse4 |
              S12. |   .4152875   .1836887     2.26   0.024     .0552641    .7753108
                   |
            pulse5 |
              S12. |    .381556   .0298758    12.77   0.000     .3230005    .4401114
                   |
           lnNBpdo |
              S12. |   .0031076     .06221     0.05   0.960    -.1188217    .1250369
                   |
            dummy1 |
              S12. |   .1652527   .0867717     1.90   0.057    -.0048168    .3353222
                   |
            dummy2 |
              S12. |  -.1451163    .076757    -1.89   0.059    -.2955572    .0053247
                   |
            dummy3 |
              S12. |    .037645   .0629186     0.60   0.550    -.0856733    .1609632
                   |
            dummy4 |
              S12. |  -.0336362   .0538104    -0.63   0.532    -.1391026    .0718303
      -------------+----------------------------------------------------------------
      ARMA         |
                ar |
               L1. |   .1258927   .1197728     1.05   0.293    -.1088577     .360643
              L12. |  -.4650684   .1305037    -3.56   0.000    -.7208509   -.2092859
      -------------+----------------------------------------------------------------
            /sigma |   .1786576   .0123286    14.49   0.000     .1544941    .2028212
      ------------------------------------------------------------------------------
```

## 5.4 Conclusions

### 5.4.1 Red light running

Analyses of crash data show that Winnipeg's photo enforcement safety program has had an impact on traffic safety. There is strong evidence showing that the photo enforcement program led to a 46% decrease in right angle crashes at intersections where cameras were installed. There was no evidence of lasting spill-over effects, i.e., other intersections without cameras in Winnipeg did not experience a comparable decrease in right angle crashes, nor did they experience an increase, for example as the result of the displacement of drivers' behaviour.

Regarding rear end crashes, the analyses do suggest the installation of cameras was associated with an initial significant 42% increase in crashes, but this was followed by a significant 19% decrease. The effects associated with the installation of the third and fourth set of cameras are no longer significant. This pattern suggests drivers may initially have used their brakes more abruptly for fear of being ticketed when approaching camera intersections and this likely led to an increase in crashes. However, the data also suggest that drivers soon adjusted their behaviour to the presence of cameras and this then led to a subsequent decrease in rear end crashes. This might be indicative of learning behaviour taking place. Other evaluations of the impact of photo enforcement have found similar results where initial increases in rear end crashes are followed by decreases when drivers become habituated to the presence of cameras and no longer brake abruptly at intersections with photo enforcement.

It warrants mentioning that the evidence for this decrease is not as strong as for the initial increase. Nevertheless, when combining both effects (i.e., the increase and decrease) the net result is an increase in rear end crashes of only 15%, rather than 42%. Further monitoring will be necessary.

The analyses also suggest there has been a spill-over effect on rear end crashes at other intersections in Winnipeg where no cameras were installed. The only significant effect that was found was a 25% increase associated with the installation of the first set of cameras. The installation of following sets of cameras was not associated with significant effects. Note that the evidence for this spill-over effect is also less strong, comparable to the evidence for the decrease in rear end crashes at 48 camera intersections. It is possible that this increase at other intersections in Winnipeg without cameras is the result of drivers incorrectly assuming that cameras are present at these intersections and, as a consequence, they used their brakes abruptly when approaching an intersection for fear of being fined. This type of behaviour can cause an increase in crashes. Further monitoring will be necessary to confirm this.

In conclusion, when considering the strongest evidence only (effects significant at 5% level), there was a 46% decrease in right angle crashes at camera intersections and a 42% increase in rear end crashes. Given that rear end crashes are typically less severe than right angle crashes and the fact that this negative side effect can be rectified using mitigating strategies such as improving signage and education about the functioning of the photo cameras, it appears the photo enforcement safety program has had a positive net effect on traffic safety in the city of Winnipeg.

When considering all the evidence (i.e., including effects that are only significant at the 10% level), it can be concluded that there was a 46% decrease in right angle crashes at camera intersections and only a 15% increase in rear end crashes. However, the evidence then also suggests there was a 25% increase in rear end crashes at other intersections in Winnipeg without cameras. Again, this would suggest mitigating strategies are required to combat these negative side effects, not only in the vicinity of camera intersections, but throughout the entire city of Winnipeg. Further monitoring will be required.

**5.4.2 Speeding**

The installation of photo enforcement cameras also appears to have had an impact on speeding related crashes. The installation of the last set of cameras was associated with a 24% decrease in injury crashes at camera intersections (effect only significant at 10% level). The analyses also suggest there were no spill-over effects of the photo enforcement cameras on injury crashes at intersections in Winnipeg without such cameras.

Regarding pdo crashes, the installation of the first set of cameras was associated with a significant 29% increase in pdo crashes at camera intersections, but this was followed by a significant 35% decrease, another significant 20% increase, and another significant

13% decrease (albeit significant at the 10% level). When only considering the strongest evidence (significant at the 5% level), the net effect is virtually zero: a 0.20% increase in pdo crashes at camera intersections. When also considering the last decrease (significant at the 10% level), the net effect is a 13% decrease in pdo crashes at camera intersections. The analyses also suggest there were no spill-over effects in pdo crashes as only a nominal 2% net increase was found based on effects significant at the 10% level.

In conclusion, when only considering the strongest evidence (significant at 5% level), there were no increases or decreases in injury crashes or pdo crashes, not at the camera intersections and not at other intersections in Winnipeg. When considering all the evidence (i.e., including effects significant at the 10% level), it can be concluded that there was a 24% decrease in injury crashes at camera intersections, a 13% decrease in pdo crashes at camera intersections and a 2% increase in pdo crashes at other intersections without cameras.

Finally, while it was possible to analyze and describe the impact of the photo enforcement program on safety levels in Winnipeg, it is more challenging to better understand how these effects were established. This is due to the fact that this evaluation was designed to assess the impact of the photo enforcement safety program as a whole, i.e., how did it impact on Winnipeg safety levels in its entirety, rather than studying specific sites or intersections. This, in combination with the lack of information or documentation regarding the criteria used in selecting locations for cameras makes it difficult to attribute the results from the time series to important aspects of the photo enforcement program, such as the number of camera locations, the timelines of installing more cameras over time, the specific locations of those cameras, or the combination of increased or enhanced educational efforts with the installation of cameras.

# 6. INTERSECTION CAMERA EXPERIMENT

## 6.1 Introduction

This section of the report describes the methods and findings of the intersection camera experiment component of the study. An evaluation design was developed in order to determine the impact of photo enforcement at intersections on both speeding and red light running. Sites that are comparable to already-existing enforcement sites of the program, but at which photo enforcement had not yet been deployed were chosen for this component of the evaluation. A quasi-experimental evaluation design was used to determine whether the implementation of the intersection safety cameras led to fewer drivers who speed and/or run red lights.

## 6.2 Methods

A before/after design with control groups was used to evaluate the impact of the intersection safety cameras on both speeding and red light running. Four experimental sites were used, i.e., sites that are comparable to already-existing enforcement sites of the program, but at which photo enforcement had not yet been deployed. More specifically, data were collected at one experimental site where the maximum speed limit is 50km/h and at one experimental site with a speed limit of 60km/h, both during the fall/winter and the spring/summer. After collecting three weeks of pre-data, i.e., data collected at the experimental sites before photo enforcement was implemented, the cameras were installed and tested during a period of two weeks and then three weeks of post-data were collected, i.e., data collected at the experimental sites after photo enforcement had been implemented at those sites.

For each experimental site (four in total: 50km/h in winter and summer and 60km/h in winter and summer), two control sites were included in the design. The use of control groups is a way to account for the influence of factors not otherwise accounted for. These control sites are sites that are comparable to the experimental sites, but at which no photo enforcement was used throughout the entire duration of the evaluation. Using these control data in the analyses will eliminate or, at least render improbable, alternative explanations for any observed changes that might otherwise be attributable to the impact of the program.

Observational data were collected during the winter of 2009-2010 (December, 2009 through April, 2010) and during the summer of 2010 (May, 2010 through September, 2010) and provided to TIRF by Tri-Star Traffic & Distributing Inc. It warrants mentioning that these data were collected with the same technology at the experimental sites and control sites. Preparations for the experiments proved more challenging than anticipated for a variety of reasons. As a consequence, there were some initial delays with the collection of these roadside survey data.

TIRF staff assisted the Traffic Safety Unit of the Winnipeg Police Service with the selection of the experimental and control sites and with tasks involved with the preparation of data collection and issues related to the data collection itself. Assistance was provided in the form of e-mail, conference calls, and one on-site visit before the data collection began. Once all the data were collected and made available, TIRF analyzed the data with Stata release 11 (see StataCorp, 2010) using logistic regression analysis.

## 6.3 Results

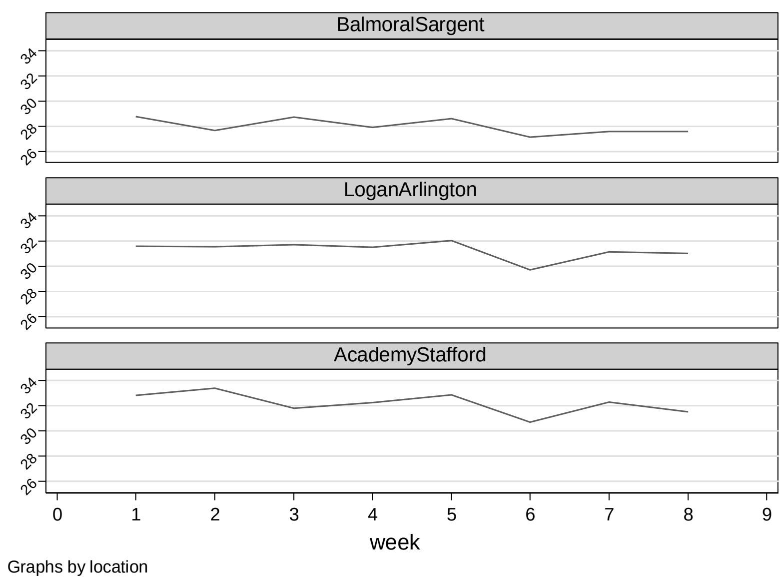
This section first describes the findings regarding speeding at intersections followed by the results regarding red light running.

### 6.3.1 Average speed

**Winter.** Figure 6-1 shows how the average speed changed over time at each 50km/h location before the installation of cameras (weeks 1-3) and after the installation (weeks 6-8). As mentioned previously, the cameras were installed and tested during weeks 4 and 5. As can be seen, there is a decrease in the average speed in the after period, although this decrease occurs both at the experimental site (Balmoral & Sargent) and the control sites (Logan & Arlington; Academy & Stafford). The difference between the experimental and control sites is that the average speed at the experimental site in weeks 7 and 8 stays comparable to week 6 whereas average speed goes up again in weeks 7 and 8 at the control sites. Nevertheless, the impact on average speed appears to be small. In fact, the average speed during weeks 1-3 at the experimental location was 28.4km/h and during weeks 6-8 it was 27.4km/h. For the first control site (Logan & Arlington) it was 31.6km/h in the before period versus 30.7km/h in the after period while it was 32.8km/h in the before period versus 31.6km/h in the after period for the second control site (Academy & Stafford). All these differences are significant according to a t-test.

While the intervention does seem to have had an impact on average speed, the impact is small. This can perhaps be explained by the fact that all three locations are located in an area where a photo enforcement program has been conducted for several years. It is possible that spill-over effects led to low average speeds in the before period. Indeed, the average speed at all three 50km/h locations in the before period is well under this maximum limit.

Figure 6-1: Average speed by week at the 50km/h experimental site (Balmoral & Sargent) and control sites in winter

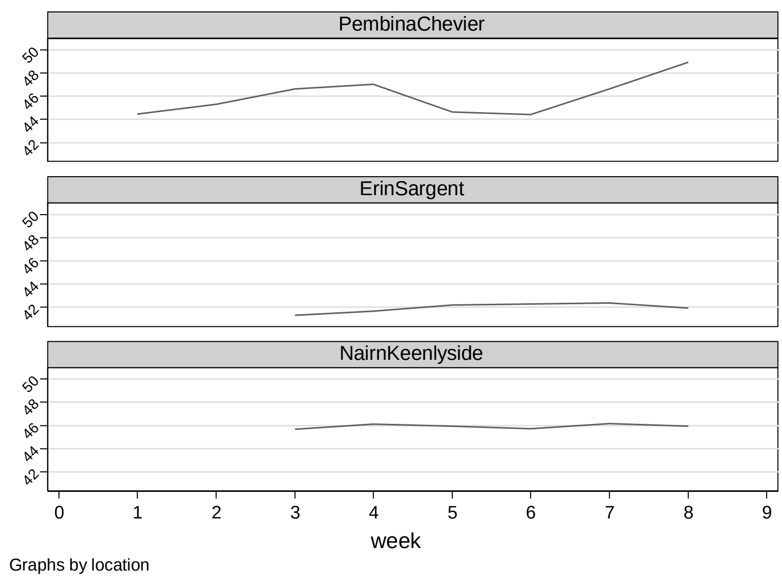



A comparable figure for three locations with a speed limit of 60km/h can be seen below (Figure 6-2). This time the intervention also seems to have an impact. The average speed decreases somewhat at the experimental site (Pembina & Chevier) from week 5 to week 6 but then it increases considerably in weeks 7 and 8. A comparable decrease between weeks 5 and 6 is not immediately apparent at both control sites (Erin & Sargent; Nairn & Keenlyside), but the average speeds stay at the same level in weeks 7 and 8. The average speed in the before period (weeks 1-3) at the experimental site was

45.3km/h and in the after period 46.6km/h. Comparable increases occurred at the control sites (from 41.3km/h to 42.2km/h at Erin & Sargent and from 45.7km/h to 45.9km/h at Nairn & Keenlyside). These differences are all significant according to a t-test.

It is possible that these small increases are due to a change in weather conditions. More precisely, data were collected from December through February at the 50km/h locations, which is in the middle of the winter. However, for the 60km/h locations data were collected from February through April so the start of data collection occurred in the winter while the end of data collection coincided with the beginning of spring. It is known that, overall, drivers adjust their driving behaviour to weather conditions so it would be expected to see this change of behaviour reflected in average speeds. If such an explanation were true, an overall increase at all locations — experimental and control — would indeed be apparent, which seems to be the case.

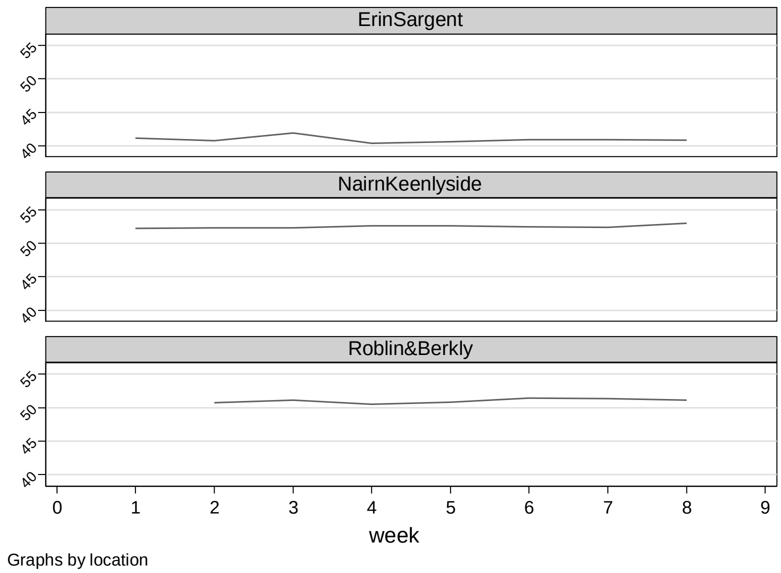
Figure 6-2: Average speed by week at the 60km/h experimental site (Pembina & Chevier) and control sites in winter




**Summer.** No valid data were available for the 50km/h sites in the summer due to unanticipated events. Constructions at a nearby intersection affected traffic patterns at the experimental location. More precisely, the installation of traffic signals at a nearby intersection led to trenching at the experimental location. As a consequence, one traffic lane at the experimental location was closed during the experiment.

Figure 6-3 contains an overview of the average speed by week for each 60km/h location in the summer. As can be seen, all three lines are rather flat. Nevertheless, an effect did take place with a small decrease in average speed from 41.2km/h to 40.9km/h at the experimental location (Erin & Sargent) and small increases from 52.3km/h to 52.6km/h at the first control location (Nairn & Keenlyside) and from 50.9km/h to 51.3km/h at the second control location (Roblin & Berkley). Again, these effects are significant.

Figure 6-3: Average speed by week at the 60km/h experimental site (Erin & Sargent) and control sites in summer




### 6.3.2 Speeding violations

As previously mentioned, logistic regression analysis was used to investigate the difference between speeding behaviour of drivers at intersections with photo enforcement compared to two control intersections without photo enforcement.

**Winter**. In terms of speeding for the 50km/h speed limit winter condition, the experimental site, Balmoral & Sargent, showed a significant decrease of 57% ((0.43-1)*100); s.e.=0.008; p=0.000) in speeding behaviour (speeding behaviour in this analysis is defined as driving at 1km/h or more over the speed limit) in the three weeks after the photo enforcement cameras were installed (weeks 6-8) compared to the three weeks before the cameras were in place (weeks 1-3). While a decrease in speeding behaviour was also apparent at the control groups, the effect at the experimental site was significantly greater (a significant interaction effect for control groups of 1.89 was found;

s.e.=0.042; p=0.000) so, overall, the reduction at the control sites was only 19% (((1.89*0.43)-1)*100).

In other words, while there was a decrease in speeding violations at all three locations, this decrease was much more pronounced at the experimental location, Balmoral & Sargent (57%), after the installation of photo enforcement cameras than at the control locations (19%) where no cameras were installed. This difference is highly significant.

```
Logistic regression                               Number of obs   =     683668
                                                  LR chi2(3)      =   12682.10
                                                  Prob > chi2     =     0.0000
Log likelihood = -177248.34                       Pseudo R2       =     0.0345

------------------------------------------------------------------------------
  speedinfr1 | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |   2.107436   .0291332    53.93   0.000     2.051103    2.165317
 post interv |   .4309078   .0083769   -43.31   0.000     .4147983     .447643
controlXpost |   1.888605   .0418207    28.71   0.000     1.808392    1.972377
------------------------------------------------------------------------------
```

Comparable analyses were conducted after filtering out those observations that took place during periods of high traffic density. More precisely, when traffic flow was greater than 900 vehicles per hour per lane for an observation, this observation was not included in the analysis. This corresponds to allowing an average of 4 seconds headway for each vehicle and limits the observations used in the analyses to those that took place when drivers were free to choose what speed to drive at, rather than being forced to go with the flow. The results were comparable, albeit somewhat more pronounced (the interaction effect is now 1.99 rather than 1.88, indicating that the reduction at control sites is even smaller:  a reduction of 57% at the experimental location versus only 15% at the control locations).

```
Logistic regression                               Number of obs   =     654964
                                                  LR chi2(3)      =   13007.75
                                                  Prob > chi2     =     0.0000
Log likelihood = -173027.75                       Pseudo R2       =     0.0362

------------------------------------------------------------------------------
  speedinfr1 | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |   2.137972   .0297075    54.69   0.000     2.080532    2.196998
post interv  |   .4286603   .0084917   -42.76   0.000     .4123358    .4456311
controlXpost |   1.988209   .0447456    30.54   0.000     1.902416    2.077872
------------------------------------------------------------------------------
```

Serious speeding violations, defined as driving at least 13km/h over the speed limit, have been investigated separately, both for all observations as well as those observations taking place during low traffic density.

As can be seen below, there is also a significant decrease in serious speeding violations at the experimental location after installation of photo enforcement cameras. The odds ratio is now 0.46 (s.e.=0.027; p=0.000) suggesting the decrease from pre to post period was 54%, while the interaction effect for control sites is now 1.37 (s.e.=0.086; p=0.000) suggesting that the reduction at control sites in serious speeding violations was only 36% (((0.46*1.37)-1)*100). This difference is highly significant. Similarly to all speeding violations, the results are somewhat more pronounced when looking at low traffic density observations only (results not displayed; odds ratio for the experimental group of 0.46 and for the control groups of 0.66 so decreases in violations of 54% and 34% respectively).

```
Logistic regression                               Number of obs   =     683668
                                                  LR chi2(3)      =    3193.53
                                                  Prob > chi2     =     0.0000
Log likelihood = -41491.782                       Pseudo R2       =     0.0371

------------------------------------------------------------------------------
 speedinfr13 | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |   3.482783    .132857    32.71   0.000     3.231884     3.75316
post interv  |   .4631659   .0265886   -13.41   0.000     .4138779    .5183235
controlXpost |    1.37252   .0859894     5.05   0.000      1.21392     1.55184
------------------------------------------------------------------------------
```

At the experimental site in the 60km/h winter condition (Pembina & Chevrier) speeding behaviour decreased by 12% (odds ratio of 0.88 ((0.88-1)*100); s.e.=0.007; p=0.000) in the three weeks after the cameras were installed compared to the three weeks before the cameras were installed. In comparison, both control locations with no photo enforcement showed significant increases in speeding behaviour of 12% (((0.88*1.28)-1)*100).

```
Logistic regression                               Number of obs   =    1148351
                                                  LR chi2(3)      =     726.83
                                                  Prob > chi2     =     0.0000
Log likelihood =  -470660.1                       Pseudo R2       =     0.0008

------------------------------------------------------------------------------
  speedinfr1 | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |    .930673   .0087413    -7.65   0.000     .9136972    .9479643
post interv  |   .8779441   .0067509   -16.93   0.000     .8648117    .8912759
controlXpost |   1.279358   .0148211    21.27   0.000     1.250636    1.308739
------------------------------------------------------------------------------
```

When only using low traffic count observations (as mentioned previously these are observations during those times when traffic count is lower than 900 vehicles per hour per lane), there appears to have been a 40% increase in speeding violations at the experimental 60km/h location after installation of photo enforcement cameras (odds ratio of 1.40; s.e.=0.014; p=0.000) but the increase is significantly greater at control locations at 57% (((1.40*1.12)-1)*100).

```
Logistic regression                               Number of obs   =     522704
                                                  LR chi2(3)      =    3307.30
                                                  Prob > chi2     =     0.0000
Log likelihood = -247363.45                       Pseudo R2       =     0.0066

------------------------------------------------------------------------------
  speedinfr1 | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |    1.01733   .0111235     1.57   0.116     .9957606    1.039367
post interv  |   1.396861   .0136834    34.12   0.000     1.370297    1.423939
controlXpost |   1.122977    .016954     7.68   0.000     1.090235    1.156703
------------------------------------------------------------------------------
```

That the increase in speeding violations was significantly higher at control locations compared to the experimental location suggests that photo enforcement still had a protective effect. Nevertheless, the data do show that there was a general increasing trend in speeding violations both at control locations as well as the experimental location. As mentioned previously, data collection for the 60km/h sites started in the winter but ended in the spring so it is possible that, everywhere in Winnipeg, people started driving faster as a result of improved weather conditions. This could explain why there is an increase in speeding behaviour at all three locations, especially in light of the fact that this particular analysis only looks at those drivers who could freely choose their speed. Key is the significant difference between the experimental and control locations confirming the increase was much greater at the control locations.

When analyzing serious violations at the 60km/h locations, a different picture emerges. At all three locations there was an increase in serious violations but the increase is now significantly higher at the experimental location. The increase at the experimental location is 83% ((1.83-1)*100), while it is only 13% at the control locations (((1.83*0.61)-1)*100). Comparable conclusions can be drawn when using low traffic data only (an increase of 114% at the experimental site versus 15% at the control sites). These differences are significant.

It appears that photo enforcement works generally speaking, but it might be less effective with drivers who tend to commit serious speeding violations, who seem to be less susceptible to this measure, at least at the 60km/h site.

```
Logistic regression                               Number of obs   =    1148351
                                                  LR chi2(3)      =     737.42
                                                  Prob > chi2     =     0.0000
Log likelihood = -89409.577                       Pseudo R2       =     0.0041

------------------------------------------------------------------------------
 speedinfr13 | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |   1.322281   .0391637     9.43   0.000     1.247707    1.401312
post interv  |   1.834562   .0429823    25.90   0.000     1.752223     1.92077
controlXpost |   .6147266   .0213033   -14.04   0.000     .5743594    .6579308
------------------------------------------------------------------------------
```

**Summer**. Comparable analyses have been conducted using data collected during the summer but only for 60km/h locations due to the previously mentioned issues at the 50km/h locations. Results from the three 60km/h locations are described below. At the experimental location, there was a significant decrease of 22% ((0.78-1)*100) in speeding violations while there was a significant increase of 13% at the control locations (((0.78*1.45)-1)*100). Results for low traffic density are a significant decrease of 27% at the experimental location and a significant increase of 22% at the control locations. Of interest, the general increase in speeding violations apparent at the 60km/h location in the winter condition is no longer apparent in the summer condition.

```
Logistic regression                               Number of obs   =    1278881
                                                  LR chi2(3)      =   70572.11
                                                  Prob > chi2     =     0.0000
Log likelihood = -678289.96                       Pseudo R2       =     0.0494

------------------------------------------------------------------------------
  speedinfr1 | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |   4.651038   .0492233   145.24   0.000     4.555555    4.748521
post interv  |   .7792545   .0119559   -16.26   0.000     .7561702    .8030435
controlXpost |    1.44644   .0230817    23.13   0.000     1.401901    1.492394
------------------------------------------------------------------------------
```

The results for serious speeding violations are as follows. There was a non-significant 3% decrease in serious speeding violations at the 60km/h experimental site (0.97; s.e.=0.02; p=0.21). More importantly, the effect at the control locations is significantly different from the experimental location. At these control locations there was a significant increase in serious speeding violations of 18% (((0.97*1.22)-1)*100). When using low traffic density data only the results are a non-significant decrease of 7% at the experimental location (0.93; s.e.=0.04; p=0.056) and a significant 32% increase at the control locations (odds ratio interaction effect=1.42; s.e.=0.06; p=0.000).

```
Logistic regression                               Number of obs   =    1278881
                                                  LR chi2(3)      =     260.07
                                                  Prob > chi2     =     0.0000
Log likelihood = -147974.32                       Pseudo R2       =     0.0009

------------------------------------------------------------------------------
 speedinfr13 | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
_Itargetsi~1 |   .7860736   .0150257   -12.59   0.000     .7571686     .816082
    _Iwhen_1 |   .9704577   .0229767    -1.27   0.205     .9264531    1.016552
_ItarXwhe_~1 |   1.215357   .0328975     7.21   0.000      1.15256    1.281576
------------------------------------------------------------------------------
```

### 6.3.3 Red-light running

Logistic regression was also used to investigate the difference between red light running behaviour of drivers at intersections with photo enforcement compared to the red light running behaviour of drivers at similar intersections without photo enforcement.

**Winter**. For the 50km/h speed limit winter condition, the number of red light running violations decreased by 26% (((0.74-1)*100); s.e.=0.010; p=0.000) at the experimental location Balmoral & Sargent in the three weeks post installation compared to before the installation of the cameras. On the other hand, the significant interaction effect for the control sites means this effect was smaller at control locations. Indeed, overall there was a more modest decrease of 21% at both control locations (((0.74*1.07)-1)*100). While the difference is not that great, it is significant.

```
Logistic regression                               Number of obs   =     760332
                                                  LR chi2(3)      =   15180.82
                                                  Prob > chi2     =     0.0000
Log likelihood =  -262452.5                       Pseudo R2       =     0.0281

------------------------------------------------------------------------------
    redlight | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |   2.423928   .0276321    77.67   0.000      2.37037    2.478695
post interv  |   .7374599   .0103418   -21.72   0.000     .7174664    .7580105
controlXpost |   1.073148   .0176115     4.30   0.000     1.039179    1.108227
------------------------------------------------------------------------------
```

To place this in perspective it is instructive to look at the patterns for both control sites separately. The control location Academy & Stafford showed a decrease (22%) in red light running violations in the same post period (((0.78-1)*100); s.e.=0.007; p=0.000). On the other hand, the control location Logan & Arlington showed a 113% increase (((2.13-1)*100); s.e.=0.109; p=0.000) in red light running violations during the same period. Thus, a larger decrease in red light running was noted at the experimental location (26%) after cameras were installed than at the control location Academy & Stafford (22%) during the same time period. Furthermore, the control location Logan & Arlington showed a large increase (113%) in red light running in comparison.

For the 60km/h speed limit winter condition, the experimental location Pembina & Chevrier where photo enforcement cameras were installed experienced a 44% decrease ((0.56-1)*100; s.e.=0.013; p=0.000) in red light running violations after the installation of the cameras. When looking at the interaction effect for control sites (1.73; s.e.=0.073; p=0.000) it is clear that the decrease at the experimental location was significantly greater than at the control locations, where it was only 3% (((0.56*1.73)-1)*100). Furthermore, when looking at the control locations separately it becomes clear that this small decrease is not significantly different from zero.

```
Logistic regression                                Number of obs   =    1161105
                                                   LR chi2(3)      =    1532.53
                                                   Prob > chi2     =     0.0000
Log likelihood = -64004.305                        Pseudo R2       =     0.0118

------------------------------------------------------------------------------
    redlight | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |   .4322175   .0144916   -25.02   0.000     .4047276    .4615746
post interv  |   .5607331    .013499   -24.03   0.000     .5348899    .5878248
controlXpost |   1.732046   .0731028    13.01   0.000     1.594534    1.881418
------------------------------------------------------------------------------
```

**Summer.** As mentioned previously, due to data issues no reliable data were available for the 50km/h sites during the summer. Results from the 60km/h sites can be seen below. There was a 40% decrease in red light running at the experimental site Erin & Sargent after installation of red light running cameras (0.60; s.e.=0.041; p=0.000). On the other hand, there was a 20% increase (((0.60*2.00)-1)*100) in red light running behaviour at the control sites (2.00; s.e.=0.151; p=0.000). These differences are significant.

```
Logistic regression                                Number of obs   =    1296689
                                                   LR chi2(3)      =     215.19
                                                   Prob > chi2     =     0.0000
Log likelihood =  -35769.77                        Pseudo R2       =     0.0030

------------------------------------------------------------------------------
    redlight | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
control site |   1.069003   .0505267     1.41   0.158     .9744206    1.172765
post interv  |   .5996644    .041489    -7.39   0.000       .52362    .6867526
controlXpost |   2.000759   .1506282     9.21   0.000     1.726282    2.318878
------------------------------------------------------------------------------
```

## 6.4 Conclusions

An examination of average speeds reveals that the extent of the impact of installing photo enforcement cameras is unclear. At the 50km/h locations in the winter, average speed decreases by a small, albeit significant amount at the experimental location (from 28.4km/h to 27.4km/h) but also at the control locations (from 31.6km/h to 30.7km/h and from 32.8km/h to 31.6km/h). At the 60km/h locations in the winter, average speeds increased significantly by a small amount at all three locations (experimental: from 45.3km/h to 46.6km/h; controls: from 41.3km/h to 42.2km/h and from 45.7km/h to 45.9km/h). It warrants mentioning that the evaluation at the 60km/h locations began in the winter (February) but ended in the spring (April) whereas the evaluation at the 50km/h locations began and ended in the winter (December through February). Improving weather conditions associated with a change of season might explain the small increases in average speeds apparent at all three 60km/h locations. If changing weather conditions was the cause of this increase it would indeed be evident both at the experimental locations as well as the control location.

As for the data collection during the summer, data from the 50km/h locations were not reliable. Data from the 60km/h location show that there was a small, significant decrease in average speed at the experimental location (from 41.2km/h to 40.9km/h) while there were small, significant increases at the control locations (from 52.3km/h to 52.6km/h and from 50.9km/h to 51.3km/h).

It appears that average speed was not sufficiently sensitive to measure the impact of photo enforcement in Winnipeg. This can perhaps be explained by the fact that the evaluation took place in an area where a photo enforcement program had been conducted for several years prior to the start of this evaluation. It is possible that spill-over effects led to low average speeds in the before period prior to the beginning of the experiment. Indeed, the average speed at all sites included in the evaluation in the before period was well under the maximum speed limit.

If there was spill-over in Winnipeg, then it is fair to assume it has equally affected all sites included in the evaluation, regardless of whether they were used as an experimental location or control location. The expectation, then, is that any effect of the impact of photo enforcement would be underestimated. Results, if any, are therefore conservative. In the extreme, this would mean no more safety gains can be made in Winnipeg by installing more photo enforcement cameras at intersections and no meaningful conclusions could be drawn from such an evaluation. However, when looking at another evaluation measure — violations rather than average speed — this does not hold true.

For the purpose of this evaluation, speeding violations were defined as driving at least 1km/h over the speed limit and serious speeding violations were defined as driving at least 13km/h over the speed limit. Results were calculated using all observations as well as only those observations that took place during low traffic density times, more precisely when traffic count was lower than 900 vehicles per hour per lane. This corresponds to allowing an average of 4 seconds headway per vehicle to limit the observations to those drivers who could freely choose their driving speed.

Regarding the 50km/h locations in the winter, decreases in speeding violations were apparent at the experimental location and the control locations but the analyses showed that the decrease at the experimental location was significantly greater: the decrease in speeding violations at the experimental location was 57% while the decrease was only 19% at the control locations. When looking at low traffic density observations only, the difference is more pronounced: a decrease of 57% at the experimental location and only 15% at the control locations. Comparable results were found when looking at serious speeding violations: a decrease of 54% in serious violations at the experimental location while the decrease was significantly lower at control locations (36%). The results are somewhat more pronounced for serious speeding violations when looking at low traffic density observations only: a decrease of 54% at the experimental location versus 34% at the control locations. Clearly, photo enforcement has had a significant impact on speeding violations and serious speeding violations, despite spill-over effects that may have affected all sites included in the evaluation.

Data from the 60km/h location in the winter show that there was a more modest, yet still significant decrease of 12% in speeding violations at the experimental site. At the control sites, however, there was a significant increase in speeding violations of 12%. When looking at low traffic density data only, an increase in speeding violations was apparent at the experimental and control locations but the increase was significantly smaller at the experimental location. The increase at the experimental site was 40% while it was 57% at the control locations. As mentioned previously, data collection for the 60km/h sites started in the winter but ended in the spring so it is possible that everywhere in Winnipeg people started driving faster as a result of improved weather conditions. This could explain why there is an increase in speeding violations at all three locations, especially in light of the fact that this particular analysis only looks at those drivers who could freely choose their speed. Key is the significant difference between the experimental and control locations confirming the increase in violations was significantly greater at the control locations.

When analyzing serious speeding violations at the 60km/h locations in the winter, a different picture emerges. The increase in serious speeding violations is 83% at the experimental location while the increase was significantly lower at the control locations (13%). Comparable conclusions can be drawn when looking at low traffic density data only (an increase of 114% at the experimental site versus an increase of 15% at the control site). It appears that photo enforcement works generally speaking (i.e., when looking at all speeding violations), but it might be less effective with drivers who tend to commit serious speeding violations. These drivers seem to be less susceptible to photo enforcement, at least at this particular 60km/h site. It should not be surprising that photo enforcement is less effective with serious offenders. In fact, many traffic safety measures are less effective with serious offenders. Often such serious offenders are recidivists or high-risk drivers who need more intensive interventions to manage their behaviour.

Regarding the 60km/h locations in the summer, there was a significant 22% decrease in speeding violations at the experimental site and a significant 13% increase at the control sites. Results for low traffic density observations are a significant 27% decrease at the experimental location and a significant 22% increase at the control locations. Of interest, the general increase in speeding violations apparent at the 60km/h location in the winter condition is no longer apparent in the summer condition. The results for serious speeding violations are as follows. There was a non-significant 3% decrease in serious speeding violations at the 60km/h experimental site. More importantly, the effect at the control locations is significantly different from the experimental location. At these control locations there was a significant increase in serious speeding violations of 18%. When using low traffic density data only the results are a non-significant decrease of 7% at the experimental location and a significant 32% increase at the control locations. The data from the 60km/h locations in the summer do not suggest photo enforcement is less effective with serious offenders. This might perhaps be explained by infrastructure differences between the experimental summer site and the experimental winter site.

The results regarding red light violations show that there was a modest, yet significant difference between the 50km/h experimental site and its control sites in the winter. More precisely, there was a 26% decrease in red light violations after installation of photo enforcement cameras at the experimental site and this decrease was only 21% at the control locations. At the 60km/h locations during the winter the decrease in red light violations was 44% at the experimental site versus a non-significant decrease of only 3% at the control locations. The results for the 60km/h locations in the summer show that there was a significant 40% decrease in red light violations at the experimental site and a significant 20% increase at the control sites.

In conclusion, this portion of the evaluation shows photo enforcement does have a protective effect on speeding behaviour. Generally speaking, there were either decreases in speeding violations at the experimental site compared to smaller decreases or increases at the control sites or there were increases in speeding violations at the experimental site that were significantly smaller than the increases at the control sites. However, the data also suggest that photo enforcement is more effective in preventing speeding violations in general but less effective in preventing serious speeding violations. This can likely be explained by the fact that serious speeding violations are more commonly committed by high-risk drivers. It is known that many traffic safety measures are less effective with such high-risk drivers because they are less amenable to changing their behaviour. The fact that this pattern of increased serious speeding violations was primarily apparent at one 60km/h experimental site while less pronounced at the other 60km/h site and not at all at the 50km/h experimental site may also suggest that there are differences in the intersection design between those experimental locations that have contributed to this different pattern. As suggested by such authors as Washington and Shin (2005) and Garber et al. (2007) such differences need further investigation in an effort to enhance our understanding of how best to implement photo enforcement.

Regarding red light running violations, the evaluation clearly shows a positive impact of photo enforcement with significantly fewer violations after installation of cameras.

# 7. PHOTO RADAR EXPERIMENT

## 7.1 Introduction

As part of the Photo Enforcement Safety Program, the Winnipeg Police Service uses mobile photo-radar cameras to detect speeding drivers at school and construction locations in the city. Data were collected to evaluate this aspect of the Photo Enforcement Program.

## 7.2 Methods

It was not possible to replicate the study design used for the evaluation of photo enforcement at intersections, as described in section 6 of this report. More precisely, no suitable control group locations were available for this portion of the evaluation. For this reason, it was decided to use a longitudinal evaluation design.

During an extended period of time, speeding behaviour of drivers was monitored at two locations, Grosvenor (a location nearby a school with a speed limit of 50km/h) and Henderson (a location nearby a school with a speed limit of 60km/h). During the monitoring period, speed enforcement took place several times, creating a series of before/after periods enabling a comparison of driver behaviour before the intervention versus during and after the intervention.

At Grosvenor, monitoring of speeding behaviour began in May 2009 and ended in February 2010. The enforcement schedule was as follows:

- June 23 - 29, 2009: 1.53 hours of enforcement;
- July 28 - August 3, 2009: 13.67 hours of enforcement;
- September 1 - 9, 2009: 1.57 hours of enforcement;
- November 1 - 30, 2009: 2.12 hours of enforcement; and,
- February 2 - 8, 2010: 5.07 hours of enforcement.

At Henderson, monitoring took place from February 2010 through August 2010. The enforcement schedule was:

- March 22-28, 2010: 13.28 hours of enforcement;
- April 5 - 11, 2010: 1.95 hours of enforcement;
- April 19 - 25, 2010: 10.37 hours of enforcement;
- June 7 - 20, 2010: 8.5 hours of enforcement;
- July 19 - August 1, 2010: 10.41 hours of enforcement; and,
- August 9 - 14, 2010: 1.55 hours of enforcement.

## 7.3 Results

Unfortunately, no meaningful results have been obtained for this portion of the evaluation, mainly for two reasons. First, due to some challenges with the monitoring device, data regarding speeding behaviour of drivers during the monitoring period were incomplete. To illustrate, no information about driver behaviour at Grosvenor is available for the periods July 29 - August 3 (enforcement took place from July 28 - August 3) and November 17 - November 30 (enforcement took place from November 1 - November 30). Comparable issues arose during other times and at the other location. As a consequence, it is unknown how drivers behaved at these locations during crucial times.

Second, as can be seen from the enforcement schedule at both locations, enforcement levels may have been too low at certain times, making it challenging to discern any changes in behaviour when conducting statistical analyses.

## 7.4 Conclusions

The use of mobile photo radar cameras is an integral part of Winnipeg's Photo Enforcement Safety Program. Therefore, data were collected to also evaluate this aspect of the Program. Unfortunately, due to limitations of the data it was impossible to draw any meaningful conclusions about the effectiveness of these mobile radar cameras. It is recommended that efforts are made to improve data collection in a follow-up study to enable the evaluation of this aspect of the Program.

# 8. CONCLUSIONS

The Traffic Injury Research Foundation (TIRF) was contracted by the City of Winnipeg to evaluate the Winnipeg Photo Enforcement Safety Program of the Traffic Safety Unit of the Winnipeg Police Service. The components of the evaluation include:

- a review of the literature about photo enforcement;
- a process evaluation of Winnipeg's photo enforcement safety program;
- a public opinion poll in Winnipeg about the photo enforcement safety program;
- an analysis of the effect of photo enforcement on traffic safety in the municipality, including annual statistics and year to year variances in:
  - traffic collisions;
  - traffic injuries; and,
  - collision severity;
- a controlled study evaluating the impact of photo enforcement at intersections on speed and red light violations; and,
- a controlled study evaluating the impact of mobile photo radar on speed at schools and construction sites.

It can be concluded that there is a large body of literature demonstrating the positive impact of photo enforcement programs. Some studies have also compared photo enforcement with other measures such as increasing the length of the yellow light phase — it warrants mentioning that yellow light timing in the City of Winnipeg has been evaluated and it was concluded that amber interval durations of 4 seconds are suitable for Winnipeg for roads with speeds up to and including 80 km/h (see Escobar 2011). While there is clear consensus that such engineering measures are necessary to improve intersection safety, researchers also generally agree that these measures are not sufficient and that further gains can be made by using additional safety measures such as photo enforcement. Nevertheless, results of a minority of studies do raise some questions about the effectiveness of this strategy. Of considerable importance, authors of these studies that question photo enforcement do not support the total abolition of photo enforcement but rather suggest that further research is needed to better understand the impact of photo enforcement at different types of intersections and under different conditions. In sum, a consensus exists among a majority of researchers in the field that photo enforcement is an effective safety measure. However, some researchers do voice concerns about undesirable side effects (such as a possible increase in rear end crashes) and encourage further research to investigate optimal conditions for these programs.

The process evaluation showed that program operations are well-managed and issues that do emerge are easily resolved and dealt with accordingly. There are, however, some issues that will require ongoing attention such as transitioning to digital technology. Other issues that will require ongoing consideration include the monitoring of revenues relative to projections; the continued monitoring of public support; and emphasis on awareness initiatives targeted towards high-risk populations. Recommendations are formulated in a separate section (see section 9 of this report).

From the public opinion poll results it is known that levels of public concern about road safety in general and specific road safety issues in particular among residents of the Winnipeg Central Metropolitan Area are in line with levels of public concern coming from other independent sources. This speaks to the credibility of the results from this public opinion poll. The actual percentage of respondents being concerned about road safety (54%) is indicative of road safety being considered to be a mid-level priority to the public. Furthermore, when looking at specific road safety issues it is clear that the public certainly is concerned about drinking driving and a clear majority is also concerned about running red lights, but fewer people seem to be concerned with speeding. There seems to be a discrepancy between the levels of concern about speeding and the actual damage caused on the roads as a result of speeding.

While it appears there is a lower level of concern among the people in the Winnipeg CMA — predominantly about the issue of speeding — virtually everybody seems to be aware of Winnipeg's photo enforcement safety program. When asked whether they knew about the program, approximately 95% confirmed they did. Moreover, the program garners rather high levels of support among people from the Winnipeg CMA: 71% believe the program helps improve road safety in Winnipeg, approximately 80% think the photo enforcement safety program makes the public more aware of the issue of speeding, and, most importantly, 81% support the continuation of the photo enforcement safety program. Also, it warrants mentioning that even among those who have previously been caught for speeding and received a ticket, the level of support for the continuation of the program is still high at about 74%. On the other hand, when people were asked about their speeding and red-light running behaviour, 28.5% admitted they had previously been caught for speeding and received a ticket and 4.5% admitted they had previously been caught for running a red light and received a ticket. This means there are still a lot of people in the Winnipeg CMA who commit such infractions. Recommended ways to increase the effectiveness of the program are described in more detail in the recommendations section.

Time series analyses of crashes revealed that the photo enforcement program has had a considerable impact on traffic safety levels in Winnipeg. On the one hand, the data show that there has been a 46% decrease in right angle crashes at camera intersections. On the other hand, the data also show there has been a 42% increase in rear end crashes.

When considering less strong evidence from these analyses (i.e., also including effects significant at the 10% level), the decrease in right angle crashes is still 46% but the increase in rear end crashes only appears to be 15% rather than 42%. The evidence then also suggests there was a 25% increase in rear end crashes at other intersections in Winnipeg without cameras. The analyses regarding speeding related data also produced some effects that were significant at the 10% level: a 24% decrease in injury crashes at camera intersections, a 13% decrease in pdo crashes at camera intersections and a 2% increase in pdo crashes at other intersections without cameras.

The evidence clearly supports that there was a strong decrease in right angle crashes and that there was an increase in rear end crashes at camera intersections in Winnipeg. This increase in rear end crashes was less pronounced than the decrease in right angle crashes, but the increase may also have occurred — to a lesser extent — at intersections without cameras due to spill-over effects. There may also have been considerable decreases in speeding related injury and pdo crashes at camera intersections, while spill-over effects of cameras on speeding related crashes are nominal or non-existent.

Considering all the evidence, and given that rear end crashes are typically less severe than right angle crashes, it appears that the photo enforcement safety program has had a positive net effect on traffic safety in the city of Winnipeg. Also, negative side effects regarding rear end crashes can and should be rectified using mitigating strategies such as improving signage and education about the functioning of the photo cameras.
An examination of data regarding the average speed collected during the intersection camera experiment reveals that the extent of the impact of installing photo enforcement cameras is unclear. At the 50km/h locations in the winter, average speed decreased by a small, albeit significant amount at the experimental location but also at the control locations. At the 60km/h locations in the winter, average speeds increased significantly by a small amount at all three locations. It warrants mentioning that the evaluation at the 60km/h locations began in the winter (February) but ended in the spring (April) whereas the evaluation at the 50km/h locations began and ended in the winter (December through February). Improving weather conditions associated with a change of season might explain the small increases in average speeds apparent at all three 60km/h locations. As for the data collection during the summer, reliable data from the 50km/h locations were not available. Data from the 60km/h location show that there was a small, significant decrease in average speed at the experimental location while there were small, significant increases at the control locations. It appears that average speed was not sufficiently sensitive to measure the impact of photo enforcement in Winnipeg. This can perhaps be explained by the fact that the evaluation took place in a city where a photo enforcement program had been conducted for several years prior to the start of this evaluation. It is possible that spill-over effects led to low average speeds in the before period prior to the beginning of the experiment. Indeed, the average speed at all sites included in the evaluation in the before period was well under the maximum speed limit.

Of importance, if there was spill-over in Winnipeg, then it is fair to assume it has equally affected all sites included in the evaluation, regardless of whether they were used as an experimental location or control location. The expectation, then, is that any effect of the impact of photo enforcement would be underestimated. Results, if any, are therefore conservative. In the extreme, this would mean no more safety gains can be made in Winnipeg by installing more photo enforcement cameras at intersections and no meaningful conclusions could be drawn from such an evaluation. However, when looking at another evaluation measure — violations rather than average speed — this does not hold true.

Regarding the 50km/h locations in the winter, decreases in speeding violations were apparent at the experimental location and the control locations but the analyses showed that the decrease at the experimental location was significantly greater. Comparable results were found when looking at serious speeding violations. Data from the 60km/h location in the winter show that there was a more modest, yet still significant decrease in speeding violations at the experimental site. At the control sites, however, there was a significant increase in speeding violations. When looking at low traffic density data only, an increase in speeding violations was apparent at the experimental and control locations but the increase was significantly smaller at the experimental location. As mentioned previously, data collection for the 60km/h sites started in the winter but ended in the spring so it is possible that everywhere in Winnipeg people started driving faster as a result of improved weather conditions. This could explain why there is an increase in speeding violations at all three locations, especially in light of the fact that this particular analysis only looks at those drivers who could freely choose their speed. Key is the significant difference between the experimental and control locations confirming the increase in violations was significantly greater at the control locations.

When analyzing serious speeding violations at the 60km/h locations in the winter, a different picture emerges. The increase in serious speeding violations at the experimental location is significantly greater than the increase at the control locations. It appears that photo enforcement works generally speaking, i.e., when looking at all speeding violations, but it might be less effective with drivers who tend to commit serious speeding violations. These drivers seem to be less susceptible to photo enforcement, at least at this particular 60km/h site. It should not be surprising that photo enforcement is less effective with serious offenders. In fact, many traffic safety measures are less effective with serious offenders. Often such serious offenders are recidivists or high-risk drivers who need more intensive interventions to manage their behaviour.

Regarding the 60km/h locations in the summer, there was a significant decrease in speeding violations at the experimental site and a significant increase at the control sites. Of interest, the general increase in speeding violations apparent at the 60km/h

location in the winter condition is no longer apparent in the summer condition. Regarding serious speeding violations, there was a non-significant decrease in serious speeding violations at the 60km/h experimental site but, more importantly, at the control locations there was a significant increase in serious speeding violations. The data from the 60km/h locations in the summer do not suggest photo enforcement is less effective with serious offenders. This might perhaps be explained by infrastructure differences between the experimental summer site and the experimental winter site.
The results regarding red light violations show that there was a modest, yet significant difference between the 50km/h experimental site and its control sites in the winter. More precisely, there was a significant decrease in red light violations after installation of photo enforcement cameras at the experimental site and this decrease was significantly lower at the control locations. At the 60km/h locations during the winter there was a significant decrease in red light violations at the experimental site versus a non-significant decrease at the control locations. The results for the 60km/h locations in the summer show that there was a significant decrease in red light violations at the experimental site and a significant increase at the control sites.

In sum, this portion of the evaluation shows photo enforcement does have a protective effect on speeding behaviour. Generally speaking, there were either decreases in speeding violations at the experimental site compared to smaller decreases or increases at the control sites; or, there were increases in speeding violations at the experimental site that were smaller than the increases at the control sites. However, the data also suggest that photo enforcement is more effective in preventing speeding violations in general but may be less effective in preventing serious speeding violations. This may be due to the fact that research shows serious speeding violations are more commonly committed by high-risk drivers. It is known that many traffic safety measures are less effective with such high-risk drivers because they are less amenable to changing their behaviour. The fact that this pattern of increased serious speeding violations was primarily apparent at one 60km/h experimental site while less pronounced at the other 60km/h site and not at all at the 50km/h experimental site may also suggest that there are differences in the intersection design between those experimental locations that have contributed to this different pattern. As suggested by such authors as Washington and Shin (2005) and Garber et al. (2007) such differences need further investigation in an effort to enhance understanding of how best to implement photo enforcement.

Regarding red light running violations, the evaluation clearly shows a positive impact of photo enforcement with significantly fewer violations after installation of the cameras.

Finally, as mentioned previously, it was not possible to draw any meaningful conclusions about the effectiveness of mobile photo radar in the city of Winnipeg due to limitations of the data.

# 9. RECOMMENDATIONS

## 9.1 Recommendations from the Process Evaluation

### 9.1.1 Recommendation 1

**Improve the documentation of key program decisions and their associated decision-making criteria.** Clear documentation of decisions and the criteria on which such decisions are based can serve some important purposes. First, official documentation by agencies of decisions involved in any implementation is important to guide staff activities and create accountability. For example, while Provincial legislation and regulations typically contain much policy direction regarding program procedures and practices, it is important that relevant decisions are also articulated at an operational level. In this case, the selection of intersection safety camera sites was largely guided by Provincial legislation. However, other practical factors were also necessarily considered as part of the site selection process although they were not stipulated in legislation. These included: public concerns about crash locations, the presence of street furniture and an appropriate power source, data pertaining to high-crash locations, and the level of safety to conduct photo enforcement.

Second, agencies may also benefit from such documentation as a strategy to promote consistency in operations. This may be particularly important in the event that programs encounter staff turnover at either managerial or operational levels; or on the part of the service providers.

Third, the documentation of decisions can further increase program transparency among political officials and the public. This may contribute to higher levels of political and public support for the program.

Finally, the ongoing documentation of key decisions and progress regarding the implementation of a program as well as timelines, can facilitate and support a rigorous program evaluation.

### 9.1.2 Recommendation 2

**Seek external input regarding financial projections associated with the program.** The amount of revenue that is generated by a photo enforcement program can be dependent upon several factors related to the nature of the contract that is entered into with the service provider. Such factors may include the number of photo enforcement tickets issued; the percentage of drivers who voluntarily pay the ticket versus challenge the ticket in court; and, the amount of the fine that is ultimately collected. Other important considerations include the magnitude of the program, staffing, the costs of technology over time, and associated program costs. Accurate program projections are needed to ensure that local governments are well-positioned to appropriately allocate resources, to manage risk, and to inform broader financial decisions.

In the case of Winnipeg's program, financial projections were difficult to gauge. Prior to implementation, a healthy revenue stream was initially projected for the program, resulting in high expectations for program revenue. These calculations were challenging to undertake due to the uniqueness of Winnipeg's program, i.e., there were no comparable programs in other jurisdictions that could be used as a baseline or measure on which estimates could be based. This resulted in projections being over-estimated.

The expected revenue estimates have since been revised in the new contract and are lower compared to the initial projections. In order to ensure that the projection method is sound, it is recommended that Winnipeg Police Service and the City of Winnipeg seek expert input on future financial projections for the photo enforcement program.

### 9.1.3 Recommendation 3

**Enhance program partnerships to improve existing data sources or to make available new data sources that can augment program measures and provide additional information regarding the photo enforcement program.** Multiple data sources and measures of a photo enforcement program are required to properly manage, evaluate and improve the effectiveness of the program. At present, the Winnipeg Police Service does rely upon multiple types of data to provide insight into and increase understanding of program operations, including program reports containing data from cameras that are produced by ACS, police crash data, and data from Manitoba Justice.

There may be additional sources of data that can potentially provide a different window on the use of photo enforcement, such as insurance data. This is assuming that insurance data sources are made available and that any data is collected in a manner that specifically facilitates insight into red-light running or speed related crashes. However, the usefulness of such data will be a function of the level of detail associated with the data and the ability of researchers to isolate particular variables within the datasets to conduct meaningful analyses.

In the case of Winnipeg's photo enforcement program, consideration was given to the use of insurance claims data collected by Manitoba Public Insurance (MPI). For example, during the site selection process, the potential to use MPI claims data in conjunction with City of Winnipeg crash data during the planning stages of the program was explored. However, this option was not feasible because it was challenging to merge MPI claims data with Winnipeg crash data. Of particular importance, the MPI claims data do not contain information on the collision configuration in a standardized format suitable for analysis, which is an important distinction given that research has shown that different types of collisions are affected differently by photo enforcement, i.e., it would not be possible to distinguish between red-light crashes and all other types of crashes that are not influenced by photo enforcement. Hence, MPI claims data provided an incomplete picture for the purposes of evaluating the program.

The Winnipeg Police Service and MPI are working closely to identify opportunities to potentially augment the collection of MPI data for this purpose. As such, it is recommended that the Winnipeg Police Service continue to work with MPI to improve available data sources for both the management and evaluation of the program.

#### 9.1.4 Recommendation 4

**Augment performance measures associated with the photo enforcement program.** Clearly defined performance measures can facilitate and support the management and evaluation of a program. Performance measures should serve as objective indicators of what a program is trying to accomplish and what is being achieved. The routine collection of such data has many purposes including, the monitoring of day-to-day operations, demonstrating quality assurance, early identification of potential problems, and ultimately program evaluation. In the short and the long-term, these data are useful to inform refinements to the program and potential improvements.

The Winnipeg Police Service currently uses a variety of performance measures for these purposes (e.g., average speeds at intersections, number of visitors to website, number of red light violations, and public opinion about the program). Augmenting existing performance measures with additional program measures is recommended to increase understanding of the program and provide new windows on its operation. Examples of additional measures may potentially include: the number of tickets that are challenged in court; the amount of court time required to process a case; the time it takes for a case to get to court; and, reasons why people challenge the tickets.

#### 9.1.5 Recommendation 5

**Explore the feasibility of and level of support for strategies to transition to digital technology.** The Winnipeg Photo Enforcement Program currently uses analogue (wet film) technology for both mobile and intersection camera systems. This has been identified as a potential issue that may have to be addressed in the future. This is due to the fact that digital cameras have become widely available for the purposes of photo enforcement. More jurisdictions have made the switch to digital technology and, as a result, fewer manufacturers are continuing to make analogue technology (utilizing wet film) available. If this trend continues, at some point Winnipeg will no longer be able to access wet film for use in its program.

The ability of Winnipeg to continue its photo enforcement program will require a transition to digital camera technology in the future. The Winnipeg Police Service is aware of this issue and is currently exploring options, feasibility and costs of making this transition in the future so that they may be prepared to manage this change if needed. ACS has agreed to work with the Police Service in the event of any transition so that it would be cost-effective and not result in interruptions in service.

An important consideration of such a transition is the need for a change in legislation to permit the transition to the use of digital equipment. A legislative amendment would be required to support this change in program operations. In the event that agreement on a legislative amendment is not reached, and wet film is no longer available, then the program would not be able to continue operations. Hence, it is recommended that the transition to digital technology be explored so that informed decisions can be reached and, if needed, a reasonable plan and timelines can be developed to effectively manage this transition.

**9.1.6 Recommendation 6**

**Consider a review of photo radar locations on an ongoing basis and in relation to conditions set out in legislation.** It would be useful to regularly review what is happening at individual locations to determine the ongoing suitability and need for photo enforcement at specific locations. This review should include an examination of the level of violations and crashes at specific intersections, any changes to street furniture, road traffic or construction, reported concerns from citizens regarding high-crash locations, feedback from the service provider, balanced use of cameras throughout a jurisdiction, and other relevant considerations. Such a periodic review will provide additional insight into program operations and may serve to identify appropriate modifications to the program (examples of strategies to select sites are available in the literature).

On a larger scale, a periodic review of photo enforcement legislation may also be warranted to review criteria associated with camera locations. Although Winnipeg's photo enforcement program is managed and delivered by the Winnipeg Police Service (and the City), the program is enabled by provincial legislation. Thus provincial legislation sets out the conditions under which the program is regulated and the criteria for locations in which photo enforcement may be employed. There are strict requirements in Provincial legislation regarding how mobile enforcement is to be deployed. Mobile radar in Manitoba is limited to school zones, playgrounds and constructions zones. This was decided, in part, to ensure that the program focused on and emphasized improved safety as a primary goal, and was not misperceived by the public or others as merely a source of revenue. The City of Winnipeg and the Winnipeg Police Service must manage the program according to these requirements.

There have been some unintended negative consequences associated with these criteria relating to the selection of photo enforcement locations. One consequence involved challenges for Winnipeg Police Service to deploy units in accordance with the strict requirements of the legislation (e.g., ensuring all conditions associated with construction zones were being achieved). Another consequence involved challenges in determining financial projections for the program. Fewer jurisdictions specifically limit in legislation the locations in which photo enforcement may be conducted, resulting in limited comparable jurisdictions on which projections could be developed, all other factors being equal.

Thus, a periodic review of the decision to limit photo radar to only specific locations is recommended. Results from this large-scale evaluation can be used to inform knowledge about program effectiveness, provide a range of insights into the different aspects of program operations, and provide a sound basis for decision-making.

## 9.2 Recommendations from the Public Opinion Poll

### 9.2.1 Recommendation 1

**Ensure levels of concern about road safety and speeding are appropriate.** It may be possible to increase the program's effectiveness by increasing support for the program. Ways of increasing support for the program were investigated in this study using a multivariate analysis into the profile of people in favor of the continuation of the program versus those who are against the continuation of the program. Several dimensions were identified that hold promise in terms of increasing support for the program. First, raising levels of concern about road safety in general and speeding in particular can serve as a lever to increase support for the program as it was found that being more concerned goes hand in hand with being more supportive of the program. Vanlaar et al. (2008) have previously identified several ways to affect levels of concern in order to encourage people to take action or become more involved. For example, if people believe that others are concerned about the issue, this will increase their own level of concern (this is known as "the bandwagon effect"); or, if people understand the risks associated with speeding and red-light running, they will likely become more concerned about it. According to the results of the current study, the expectation would be that the increased level of concern would then lead to a higher level of support for the continuation of the program. This would presumably result in more people abiding by the rules with less speeding and red-light running infractions as a result.

### 9.2.2 Recommendation 2

**Continue to educate those who are less supportive of the photo enforcement safety program about how it improves road safety.** Second, if you can convince those who are less supportive that Winnipeg's photo enforcement safety program helps improve road safety and makes the public more aware of the issue of speeding, levels of support for the continuation of the program among them would likely rise. This begs the question how those people who are against the continuation of the program can be convinced of its virtues. To this end, a strategy could be developed based on social marketing research findings regarding strategies to make people understand how risky these behaviours are and showing that the majority of people truly are concerned about these issues. Other potential dimensions of interest include the magnitude of the problem. People may underestimate the true magnitude of the problem so if they would understand what the true extent of the problem is, they may no longer underestimate it and become more concerned about it as a result; this would in turn lead to higher levels of support for the program.

### 9.2.3 Recommendation 3

**Convince offenders that their behaviour is dangerous.** It may also be useful to ensure that people who are caught and received a ticket — primarily for speeding although logic dictates the same would be true for running red lights — understand their behaviour is dangerous. It was found that having been caught and received a ticket influences the level of support. More precisely, among those who have been caught, support for the continuation of the program is lower. To actually make this subgroup aware of their dangerous behaviour may require a tailored approach because they may be less receptive of general social marketing strategies. Perhaps it could be investigated if and how this subgroup could be encouraged to be more cognizant of the risks they impose on other road users because of their behaviour. If they would understand why they are being sanctioned they may better appreciate the consequences and would perhaps become more supportive. As a sidebar, it is likely not impossible that at least a portion of them would become supportive, as suggested by the finding that 74% of those who were caught indeed actually are supportive of the program. On the other hand, it is acknowledged that not all people who committed infractions will be receptive to such a strategy. There will always be persistent offenders with whom such a rational approach would not work. The results from this study confirm this as several respondents indicated they were caught for speeding and running red lights at least three times, indicative of persistent or 'hard-core' offenders.

## 9.3 Recommendations from the Time Series Analyses

### 9.3.1 Recommendation 1

**Design a strategy to mitigate the negative side effect regarding the increase of rear end crashes associated with the use of photo enforcement.** As mentioned previously, the photo enforcement program has had a positive net effect on traffic safety levels in the city of Winnipeg. Nevertheless, the evidence does show there has been an increase in rear end crashes at camera intersections and likely at other intersections in Winnipeg too. For this reason, a strategy should be designed that can help mitigate this increase in rear end crashes. Such a strategy can include improved signage regarding the use of photo enforcement to ensure drivers get sufficient notice when approaching an intersections as well as education for drivers about this negative side effect.

### 9.3.2 Recommendation 2

**Further monitor crash levels in Winnipeg.** Results from the time series analyses provided insight into crash patterns associated with the use of photo enforcement. However, not all the evidence was equally strong (i.e., some effects were only significant at the 10% level rather than the 5% level). It is recommended to update the analyses when more crash data become available so these effects can be further monitored and investigated.

### 9.3.3 Recommendation 3

**Conduct further research to shed light on mechanisms that can help explain why the photo enforcement safety program is effective and how it can best be improved.** Of importance, while it was possible to analyze and describe the impact of the photo enforcement program on safety levels in Winnipeg, it is more challenging to better understand how these effects were established. This is due to the fact that this evaluation was designed to assess the impact of the photo enforcement safety program as a whole, i.e., how did it impact on Winnipeg safety levels in its entirety, rather than studying specific sites or intersections. This, in combination with the lack of information or documentation regarding the criteria used in selecting locations for cameras makes it difficult to attribute the results from the time series to important aspects of the photo enforcement program, such as the number of camera locations, the timelines of installing more cameras over time, the specific locations of those cameras, or the combination of increased or enhanced educational efforts with the installation of cameras. Therefore, shedding more light on how these different aspects interplay and which permutations of these combined aspects work best in terms of increasing the program's effectiveness and efficiency is recommended.

## 9.4 Recommendations from the Intersection Camera Experiment

### 9.4.1 Recommendation 1

**Conduct further research into the profile and behaviour of offenders who commit serious violations.** Generally speaking, the evaluation results suggest photo enforcement has a protective effect leading to fewer speeding violations and red light running violations. However, the data also suggest that photo enforcement is more effective in preventing speeding violations in general but may be less effective in preventing serious speeding violations. This can likely be explained by the fact that serious speeding violations are more commonly committed by high-risk drivers. It is known that many traffic safety measures are less effective with such high-risk drivers because they are less amenable to changing their behaviour. Further research into the profile and behaviour of offenders who commit serious violations will be useful in determining how such offenders should be managed and how the photo enforcement program can be further improved.

### 9.4.2 Recommendation 2

**Conduct further research into infrastructure and engineering differences between intersections that may explain differences in performance of photo enforcement at intersections.** The fact that this pattern of increased serious speeding violations was primarily apparent at one 60km/h experimental site while less pronounced at the other 60km/h site and not at all at the 50km/h experimental site suggests that there may be differences in the intersection design between those experimental locations that have contributed to this different pattern. As suggested by such authors as Washington and Shin (2005) and Garber et al. (2007) such differences need further investigation in an effort to enhance understanding of how best to implement photo enforcement. A further examination of the literature along with a detailed and controlled experiment might provide further insight into this issue.

## 9.5 Recommendations from the Photo Radar Experiment

### 9.5.1 Recommendation 1

**Conduct a follow-up study to enable the evaluation of the effectiveness of photo radar.** The use of mobile photo radar cameras is an integral part of Winnipeg's Photo Enforcement Program. Therefore, data were collected to also evaluate this aspect of the Program. Unfortunately, due to limitations of the data it was impossible to draw any meaningful conclusions about the effectiveness of these mobile radar cameras. It is recommended that efforts are made to improve data collection in a follow-up study to enable the evaluation of this aspect of the Program.

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# APPENDIX 1: Timeline of Critical Actions

| Winnipeg Photo Enforcement Program timeline of critical actions | |
|---|---|
| 1994 | Winnipeg Police Service (WPS) first requested legislative amendment to permit the use of photo radar. |
| 1997 | WPS discussion with the Province following a series of public forums where citizens identified traffic safety as a primary safety concern. |
| June 28, 1997 | Passage of un-proclaimed red light legislation – The Highway Traffic Amendment, Summary Convictions Amendment and Consequential Amendments Act. |
| May 2000 | Formal request made by council to enact legislation to enable the use of photo radar. |
| October 19, 2001 | Winnipeg Police Service (WPS) began six month pilot project where one intersection safety camera was installed at a high collision intersection compared to traffic volume (Sherbrook St. and Broadway). |
| May 8, 2002 | The Standing Committee on Law Amendments (Legislative Assembly of Manitoba) met to discuss Bill 3 – The Highway Traffic Amendment and Summary Convictions Amendment Act. |
| March 22, 2002 | Request for Proposal (RPF) issued to select the contractor for the supply, installation and operation of the program. |
| May 23, 2002 | Highway Traffic Amendment and Summary Convictions Amendment Act passed into legislation. |
| May 31, 2002 | Province entered into agreement with the City and ACS Public Sector Solutions Inc. with an information access agreement which recognizes ACS as the photo enforcement service provider and provides them with access to registered vehicle owner's information from the Manitoba Division of Driver and Vehicle Licensing. |
| June 17, 2002 | Tender issued to select contractor to supply mobile photo radar operators. |
| August 30, 2002 | Canadian Corps of Commissionaires awarded contract and responsible for providing 18 staff to operate the mobile radar vehicles. |
| Fall 2002 | The first 12 intersection camera locations were tested. |
| November 2002 | Mobile photo radar 'warning phase' began. |
| December 11, 2002 | City entered into agreement with the Province – *Conditions of Authority* – under which the terms and conditions under which the City's authority for the program is subject. |
| December 16, 2002 | *Image Capturing Enforcement Regulation* came into force authorizing the city to begin photo enforcement. |
| January 6, 2003 | Two month warning phase of the program at the City's 12 Intersection Safety Camera (ISC) locations. |
| January 7, 2003 | WPS began issuing tickets for speeding and red light offences at the 12 Intersection Safety Camera locations, and mobile radar units were used in school and playground zones and constructions sites. |
| August 2003 | 12 additional cameras were added to the program. |
| July 2004 | Six additional cameras were added to the program. |
| August 2004 | Six additional cameras were added to the program. |
| July 2005 | Six additional cameras were added to the program. |
| August 2005 | Six additional cameras were added to the program. |
| June 2006 | Number of Photo Radar vehicles went from 5 to 10. |
| 2007 | Contract with ACS was extended for five more years. |
| 2008 | Awareness initiatives were expanded and became more targeted. |
| July, 2009 | ACS elected to change subcontractors from the Corps of Commissionaires to Traffic Safe Solutions. |

# APPENDIX 2: Public Opinion Survey

## Public Opinion Poll Photo Enforcement Safety Program Winnipeg

**INTRO.** Good afternoon\evening, my name is _______________ and I am calling from Opinion Search, a national research firm based in Ottawa. We have been commissioned by the Traffic Injury Research Foundation to ask people who have driven a car in the last 30 days about a road safety program in Winnipeg. Will you please help us by answering some questions; it will only take about five minutes?

- Yes – Continue to survey
- No - No time now - Callback
- No one has licence and driven in past 30 days – **Thank and Terminate**
- No - Refused (try to convert respondent using info on the next screen)

**REFUSAL CONVERSION.** All the answers you give will be kept in the strictest of confidence and used for program evaluation purposes only. Your answers can help improve traffic safety in Winnipeg and it should only take about five minutes or so. May I continue?

- Yes – Continue to survey
- No - No time now - Callback
- No – Refused – **Thank and Terminate**

**SURVEY**

**q1.** I'd like to ask you some questions about current issues. I'm going to read you a short list of items and for each one I'd like you to tell me how concerned you are about it, using a scale of 1 to 6, where 1 means you are not at all concerned, and 6 means you are extremely concerned. The first is… (ROTATE)

**q1a.** The price of gas at the pumps
**q1b.** Global warming
**q1c.** Road safety in general

**q2.** Using the same 6 point scale, I'd like to ask you some questions about traffic safety issues. The first is… (ROTATE)

**q2a.** Speeding
**q2b.** Drinking Drivers
**q2c.** Drivers who run red lights

**q3.** Did you know that the city of Winnipeg runs a photo enforcement safety program to increase road safety in Winnipeg by reducing the number of speeding and red light violations? **Yes/No**

**IF YES TO q3:**

**q4.** How did you find out about this program? **(check all that apply)**

**q4a.** I heard about it from a relative or friend;
**q4b.** I read about it in the newspaper;
**q4c.** I heard about it in the news on the radio or TV;
**q4d.** I heard about it on TV in an advertisement;
**q4e.** I read about it on the Internet.
**q4f.** I noticed traffic signs in the street or at intersections that indicate speeding and running red lights are being enforced using radars or photo cameras;
**q4g.** I was caught speeding and received a ticket;
**q4g1.** If checked: how many times?_____
**q4h.** I was caught running a red light and received a ticket;
**q4h1.** If checked: how many times?_____
**q4i.** Other:____________________________________.

**q5.** Do you believe this program helps improve road safety in Winnipeg? **Yes/No**

**q6.** Do you believe this program makes the public more aware of the issue of speeding? **Yes/No**

**q7.** Has this road safety program affected your own driving behaviour in traffic? **Yes/No**

**If yes to q7 (check all that apply):**

**q7a.** Yes, I slowed down in traffic because of this program;
**q7b.** Yes, I have become more cautious when crossing an intersection because of this program;
**q7c.** Yes, I have become a better driver overall because of this program.

**q8.** Do you support the continuation of this program? **Yes/No**
**go to q13**

**IF NO TO q3:**

"The photo enforcement program in Winnipeg was established in 2003 to enhance road safety in the city by using camera enforcement to reduce the number of speeding and red light violations. The Winnipeg Police Service uses cameras at 48 locations and mobile radars to catch drivers who speed or run red lights."

**q9.** Do you believe this program helps improve road safety in Winnipeg? **Yes/No**

**q10.** Would such a program have affected your own driving behaviour in traffic if you had been aware of the program? **Yes/No/Perhaps**

**q11.** Do you support the continuation of this program? **Yes/No**

**q12.** In the last six months, have you received a ticket:

**q12a.** For running a red light in the city of Winnipeg? **Yes/No**
**q12a1.** If yes, how many?____
**q12b.** For speeding in the city of Winnipeg? **Yes/No**
**q12b1.** If yes, how many?____

**ALL:**

**q13.** How many traffic tickets have you had in total in the past 12 months? (Parking tickets not included.)____

**q14.** Have you ever been injured in a motor vehicle accident? Only count injuries that required medical attention. (Includes injuries sustained as driver, passenger, pedestrian, etc.) **Yes/No**

**q15.** How many traffic collisions have you had in the past 12 months as a driver?____

**q16.** Approximately how many kilometers do you drive in a typical month? _______km

**q17.** What is your age please? ______

**q18.** Which of the following best describes your family status?
READ LIST ONLY IF NECEESARY

- Single, never married
- Married (or living with a partner)
- Separated or Divorced
- Widow/Widower

**q19.** (NOT ASKED) Gender