Picture This—Mobile Photo Radar and Its Efficacy on Traffic Safety

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Executive Summary

Project Objectives

This Master's Project was designed to assess whether mobile photo radar reduces the frequency of collisions, thereby saving lives and reducing the number of major and minor injuries as well as property-damage-only events.

Strathcona County Councillor Brian Botterill, who was responsible for the motion to cease mobile photo radar operations in Sherwood Park, Alberta, Canada is the project client. Councillor Botterill requested a before-and-after analysis of mobile photo radar to further understand how automated camera enforcement influences traffic safety in Sherwood Park given the evidence available.

This project's purpose was to understand how mobile photo radar affects traffic collisions in a municipality. The main research question was, "Does the presence of mobile photo radar have a significant impact on the number of vehicle collisions in Sherwood Park, Alberta?" The project analyzed how the discontinuation of mobile photo radar has affected safety in Sherwood Park and the likelihood of a vehicle having a collision in Sherwood Park following the discontinuation of mobile photo radar. The research examined traffic safety data from 2001 to 2012 when mobile photo radar was operational, as well as from 2012 to 2016 when the automated technology was discontinued (R. Anders, personal communication, April 10, 2017).

This project aims to contribute to the body of knowledges and debate on automated enforcement technology by examining before-and-after results on motor vehicle collisions. This project appears to be the first study of its kind to explore what happens to traffic safety following the removal of mobile photo radar in a municipality.

Defining the Problem

In Canada, as in most countries, exceeding the speed limit is a common traffic offense (Tay, 2010, p. 248). Delaney, Ward, Cameron, and Williams (2005) observed that speed limits, intended to control top speeds, are frequently ignored, and vehicle speed capabilities far exceed posted speed limits, making traffic enforcement necessary for public safety (p. 404).

While the most common traffic enforcement method involves the deployment of police officers using radar and laser equipment to identify and issue tickets to violators, governments are increasingly turning to other forms of automated, or unstaffed, traffic enforcement (Askland, 2013, p. 2; Delaney et al., 2005, p. 405).

Also known as automated speed detection, speed cameras, and mobile speed enforcement, this technology has been widely used throughout North America, Europe, and Australia with the goal of reducing the total number and severity of traffic collisions. Although photo radar purports to save lives, evidence supporting this argument is mixed and contentious.

Of the automated traffic enforcement tools available to law enforcement, few are as controversial and polarizing as mobile photo radar. Delaney et al. (2015) reported that photo radar is controversial wherever used (p. 404). Proponents tout the technology's safety benefits of reducing speeds and saving lives whereas opponents argue that 'greed and not speed' is the true motivation behind speed camera units since they can generate significant revenues for government coffers.

In addition, research indicates that the number of lives lost in road collisions, at least in developed countries like Canada, has trended downward in recent decades (Gopalakrishnan, 2012, p.144). Canada has reported a decrease in all fatality, serious injury, and total injury categories. Even the total number of fatalities per billion kilometers travelled is the lowest on record (Transport Canada, 2014, p.2). Despite the statistics, many jurisdictions are choosing to increase enforcement activities through the use of automated speed camera technology. Wilson et al. (2006) argued that automated speed enforcement has the capability of being a substantial net revenue-raising activity, blurring the line for the public as to whether the technology is used for safety or fiscal considerations (p. 3).

In 1997, Strathcona County began to operate mobile photo radar in Sherwood Park. Initially, peace officers used unmarked vehicles on or near public roadways to capture speeding violations. As technology advanced, new forms of mobile photo radar became available and were adopted by the municipality, including a stand-alone device disguised as a utility box that did not require a vehicle to operate it. This change marked the beginning of a contentious public debate over the merits of automated cameras and the significant revenues they generated. When the speed camera device box was introduced, revenue from mobile photo radar jumped nearly $700,000 over the previous year, making it the largest enforcement revenue increase within a 4-year period (J. Peebles, personal communications, October 30, 2016).

Led by Councillor Brian Botterill, a motion was made to Strathcona County Council to cease mobile photo radar operations. The motion passed by the narrowest of political outcomes, 5 votes to 4, and on September 1, 2012, mobile photo radar units were removed from the municipality. Since then, there have been lingering traffic safety questions about whether Council, including Councillor Brian Botterill, made the correct decision to remove mobile photo radar, especially when the majority of municipalities surrounding Sherwood Park continue to operate automated speed enforcement cameras.

Methodology and Methods

The project used an interrupted time series design, whereby any collision involving a fatality, major or minor injury, or property damage was measured and compared to a time when the intervention of mobile photo radar did not exist.

The literature review examined various studies that explored the effects of automated enforcement technology. Overwhelmingly, these studies evaluated photo radar following its implementation and operation in a specific jurisdiction. This project took a different approach by evaluating what happens to traffic safety when mobile photo radar has been operational and has then been removed from a municipality. Researchers such as Chen and Warburton (2006) have questioned whether collisions "rebound" (p. 675) after the cancellation of mobile photo radar programs. This project was designed to help answer that question.

Using an interrupted time series research design approach, the project statistically tested data from Strathcona County's Traffic Crash Location System (TCLS) for Sherwood Park, Alberta. Over a 16-year period, more than 17,000 observed collisions, injuries, and deaths were measured repeatedly for the population with and without the treatment condition of mobile photo radar.

Using traffic data supplied by Strathcona County (R. Anders, personal communication, April 10, 2017), as well as the number of violation tickets issued and revenue generated by mobile photo radar (G. Einarson, personal communication, April 21, 2017), the project conducted a variety of statistical tests, including graphing monthly, quarterly, and annual collision events and then determining the presence of stationarity in the time series analysis. This was followed by Ordinary Least Squares regression analysis to determine the linear relationship between the presence and absence of mobile photo radar and the number of collisions per month. Next, a Chow Test was conducted to determine whether regression coefficients are different for the data sets and whether one or two separate regression lines best fit a split set of data following the removal of mobile photo radar. Finally, a Poisson Distribution was conducted to ascertain the probability of a specific number of collisions occurring in a certain month, one using data when mobile photo radar was present, and the other using data for when it was absent.

Key Findings

Utilizing raw data counts provided by Strathcona County's TCLS (R. Anders, personal communication, April 10, 2017), initial observable research appeared to indicate a trend for an increase in total number of collisions per year. However, once monthly and quarterly mobile photo radar collisions were scaled to population, visible dips appeared in the number of collisions following the removal of mobile photo radar during the 2012 to 2016 period.

Testing for other extraneous factors, including monthly mobile photo radar revenues, the number of mobile photo radar violations, and weather-related activities, the results show that weather has a much greater impact on the number of traffic collisions than photo radar revenues or violation tickets issued. In fact, while the presence of automated technology is shown to have a technically negative effect on the number of collisions, the effect is miniscule and outweighed by other factors.

Finally, the Poisson Distribution supports the other findings by providing the probability peak of collisions with and without mobile photo radar. According to the distribution, there are likely to be 73 collisions within a month when mobile photo radar is present and 74 collisions in a given month when photo radar is absent. This serves as further evidence that there is no statistical evidence between the presence and absence of photo radar and the frequency of traffic collisions per month.

Several limitations and delimitations influenced the project. Despite the removal of mobile photo radar, other types of automated enforcement, such as speed on green and red light cameras, continued to operate in the municipality. Other variables including road engineering and construction, public education, hiring of additional enforcement officers, environmental factors, and traffic counts were not controlled for in the project, making the results vulnerable to changes in general conditions that may be relevant to mobile photo radar's impact on traffic safety. One of the key limitations was the data quality related to the hours of operation of mobile photo radar in Sherwood Park (G. Einarson, personal communication, April 21, 2017). Several months indicated impossibly high numbers of enforcement hours, including 10,359 hours in March 2009 or the equivalent of 334 hours per day. This limitation prevented the study from analyzing whether hours of mobile radar enforcement were correlated to collision rates.

Based on the available data, there is no evidence to suggest that there is a significant correlation between presence of mobile photo radar and traffic collisions. Ultimately, more data, including frequency and hours of mobile photo radar enforcement, are necessary to establish whether mobile photo radar enforcement is responsible for reductions in fatalities, major and minor injuries, and property-damage-only collisions.

Recommendations

Based upon the literature review and statistical analysis, seven recommendations are provided to the client relating to future research opportunities, data collection methods, and best practices for traffic enforcement:

Recommendation 1: Set performance benchmarks for all types of collision data captured in the Traffic Crash Location System (TCLS) and continue to collect data for future longitudinal studies. Strathcona County's (2014) *Traffic Safety Strategic Plan 2020* targeted reductions in the average annual rate of combined fatal and major-injury collisions, but it did not commit to reducing minor injuries and property-damage-only collisions. In order to improve overall traffic safety in the municipality, benchmarks should be set for all types of collision events.

Recommendation 2: Traffic enforcement in Sherwood Park should be weighted more towards specific deterrence than general deterrence to reduce the total number of collisions. Male drivers between the ages of 18 and 19 have the highest fatality rates in the province (Alberta Transportation, 2015), and according to Strathcona County's *2015 Traffic Safety Survey* results, a higher percentage of males reported it was safe to travel 10 to 15 km/h or more over the posted speed limit. When police officers target motorists with the highest risk factors and greatest propensity for speeding, they may reduce the number and severity of traffic collisions and increase overall traffic safety through specific deterrence. For example, police services can use traffic data to create lists of the worst traffic offenders and direct officers to patrol specific neighbourhoods, monitor motorists when necessary, and issue tickets when violations occur.

Recommendation 3: Using public opinion surveys, seek feedback on mobile photo radar as a traffic tool. Although mobile photo radar has been discontinued in Sherwood Park, it is still important to assess public opinion on the technology's usage as a traffic safety tool. Public opinion surveys may help researchers and public administration officials to understand the causes of the speeding paradox, where speeding is identified as a serious traffic safety risk and yet motorists do not abide by, and in some cases significantly exceed, posted speed limits.

While Strathcona County's *2015 Traffic Safety Survey* included open-ended questions on how to address residential speeding concerns, future survey instruments should consider posing direct questions about the use of a variety of speed reduction tools, from speed boards to mobile photo radar. This information will better inform elected officials on the level of public support for various traffic safety enforcement and educational tools.

Recommendation 4: Conduct a time series analysis following the removal of mobile photo radar in a given jurisdiction. This project appears to be the first to analyze how the discontinuation of mobile photo radar affects traffic safety in a municipality. More research is needed to confirm the project's findings. Jurisdictions that have discontinued mobile photo radar operations, such as British Columbia, Ontario, and Drayton Valley, Alberta are ideal cases to study how the removal of mobile photo radar has impacted collision activities.

Recommendation 5: Increase enforcement transparency. A list of enforcement locations should be published, including the reasons for their inclusion as a traffic safety hot spot. This added level of transparency helps to defend against accusations that mobile photo radar is being used for revenue generation. Selected locations should be collision-prone areas.

Further, municipalities should publish an annual breakdown of where photo revenue is spent. If violation tickets are mailed, a web link should be added to the violation ticket, envelope, brochure, or a combination thereof, so violators know where traffic revenue is directed by the municipality. As photo radar is a traffic violation, the project recommends that the vast majority of revenue, 70 per cent or more, be directed towards traffic safety capital, traffic safety operations, traffic safety initiatives, and traffic education programs.

Recommendation 6: Create a traffic enforcement matrix to increase safety. Mobile photo radar is only one of the available traffic enforcement options. Ongoing research is required so municipalities and law enforcement can evaluate the efficacy of different speed reduction tools. Additional research, including a matrix with a variety of traffic enforcement tools, will allow municipalities to utilize resources in the most effective and efficient manner, and ultimately enhance overall traffic safety.

Recommendation 7: Improvements needed to the Traffic Collision Location System. Strathcona County should be commended for its investment and usage of its Traffic Collision Location System (TCLS). This project would have not been possible without the valuable data contained within it. However, more data, specifically weather conditions, would be invaluable for future research. Using Environment Canada's weather forecast, data can be entered into the system to help better understand how intervening variables such as rain, snow, and ice influence traffic collisions. The Alberta Motor Association classifies roads using the following categories: unreported; closed; covered; partially; and bare. The municipality could adopt these categories or create its own unique terms to describe its road conditions.

It is posited that the presence or absence of mobile photo radar does not have a significant impact on the number of monthly vehicle collisions in Sherwood Park, Alberta. To conclude, the present body of knowledge on mobile photo radar requires a stronger evidence base to solidify claims about the effectiveness of automated camera speed technology as an enforcement tool to reduce the number of fatalities, major and minor injuries, and property-damage-only collisions.

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1.0 Introduction

Globally, traffic collisions are one of the leading causes of injuries and deaths (World Health Organization, 2013, p. vii). Of the variables at work in a traffic collision, few are as examined and appear to be understood as speed (Benekohal, Wang, Chittuir, Hajbabai, & Medina, 2009 p. 89; Kelley, 2005, p. 416). The relationship between speeding and the likelihood of being involved in a crash is based on physics. The faster a vehicle travels, the less time a driver has to react to changing driving conditions. When a collision occurs, there is a rapid change in velocity and more energy is absorbed by the occupants, which increases their risk of serious injury or death.

A sizeable body of literature exists to demonstrate the relationship between relative and absolute excess in speed and traffic collisions, injuries, and deaths (Elvik, Hoye, Vaa, & Sorenson, 2005, p. 48; Evans, 2004b, p. 1; Goldenbeld & van Schagen, 2005, p. 1135; Kelly, 2005, p. 416; Redelmeier & Bayoumi, 2010, p. 15). Wilson, Willis, Hendrikz, and Bellamy (2006) noted, “The need for governments to regulate and monitor speed limits is not in doubt” (p. 27). What does appear to be in doubt is whether mobile photo radar has a direct influence on traffic safety (Traffic Research Foundation, 2011).

In Canada, as in most countries, exceeding the speed limit is a common traffic offense (Tay, 2010, p. 248). Delaney, Ward, Cameron, and Williams (2005) observed that speed limits, intended to control top speeds, are frequently ignored, and vehicle speed capabilities far exceed posted speed limits, making traffic enforcement necessary for public safety (p. 404). Generally, there are two types of enforcement: conventional and automated. While the most common traffic enforcement method involves the conventional deployment of police officers using radar and laser equipment to identify and issue tickets to violators, governments are increasingly turning to other forms of unstaffed traffic enforcement (Delaney et al., 2005, p. 404). Known as automated speed detection, speed cameras, and mobile speed enforcement, this technology has been widely used throughout North America, Europe, and Australia with the promise of reducing the total number and severity of traffic collisions.

Few traffic enforcement tools are as controversial and polarizing as mobile photo radar. While supporters assert the traffic safety benefits of automated cameras (Li, El-Basyouny, & Kim, 2014, p. 3), opponents have questioned the use of photo radar as tool to generate revenue for government coffers. Others, including Mike Steneker, a former RCMP officer with 32 years of service, reported that “photo radar does not make the roads safer and that speed is just easy to enforce compared to the real culprits” (as cited in Staples, 2016b, para. 4). Steneker reviewed collision reports over a 10-year period in the Leduc area, a city located southwest of Sherwood Park, Alberta. According to Steneker’s findings, “Not one traffic injury could be blamed on speed” (as cited in Staples, 2016b, para. 5). Instead, injuries and fatalities were caused by driving while distracted or impaired, merging too slowly, failing to properly maintain vehicles, failing to wear seatbelts, and parking on the side of the road. Steneker believes that the public has been “brainwashed that speed is everything” when it comes to traffic safety (as cited in Staples, 2016b, para. 6).

Compared to conventional enforcement, proponents argue automated enforcement offers several benefits. It requires fewer police resources to enforce speeding violations, can be easily rotated among multiple sites, and is a safer alternative than having police officers attempting to pull over vehicles in busy intersections and roadways. Li et al. (2014) concluded, “Conventional enforcement is not suitable for high traffic volume locations and may cause risks to officers and the public during the operation” (p. 3).

Public and policy debates continue about the efficacy of mobile photo radar since automated enforcement does not directly address other forms of dangerous driving behaviours, including impaired, distracted, or aggressive driving (Askland, 2013, p. 7). Wilson et al. (2006) argued that automated speed enforcement has the capability of being a substantial net revenue-raising activity, blurring the line for the public as to whether the technology is used for safety or fiscal considerations (p. 3). Widespread concerns about municipalities using photo radar as a cash grab have resulted in the Alberta Government initiating a review into the province’s automated enforcement guidelines (Graney, 2017, para. 1).

This project aims to contribute to the body of knowledge and debate on automated enforcement technology by examining before-and-after results of mobile photo radar on motor vehicle collisions in Sherwood Park, Alberta. This study conducted an analysis of 16 years of statistical monthly traffic collision data, a period in which photo radar was operational (January 2001 to September 2012) and then removed from the municipality (October 2012 to September 2016). Unlike the literature review, which explored studies which examined the effects of automated enforcement technology following its introduction, implementation, and evaluation into a jurisdiction, this is the first project to have examined the issue from the opposite direction in terms of what happens to traffic safety when mobile photo radar is operational and then removed from a municipality.

1.1 Defining the Problem

This project sought to address whether mobile photo radar reduces the frequency of collisions, thereby saving lives, reducing the number of major and minor injuries, and lessening property-damage-only events. It explored whether the presence of automated enforcement has a significant statistical effect independent from that of the deployment of police officers who enforce speed limits and promote traffic safety. If the results showed a significant statistical correlation, it could be hypothesized that mobile photo radar plays a role in saving lives and preventing injuries.

At the same time, several intervening variables posed possible limitations to the research findings. The project did not control for road engineering or construction, public education, enforcement activities, environmental factors, or traffic counts, which may have influenced the findings.

It is critical for decision makers to evaluate traffic safety policies, programs, and practices using data-driven information. When a traffic safety practice, program, or policy is evaluated with statistical rigor, it assists elected officials, administrative leaders, and law enforcement officials to measure its effectiveness, with the ultimate goal being to increase the safety and well-being of residents and motorists.

On September 13, 2011, the project client, Councillor Brian Botterill, formally questioned the efficacy of mobile photo radar. Councillor Botterill made a motion "that Council direct Administration to cease operation of mobile speed cameras" (as cited in Strathcona County, 2011a, p. 3). Strathcona County Council approved the motion by the slimmest of political margins with a vote of 5 to 4. Nearly 5 years after the vote, questions remain about how ceasing mobile photo radar operations have impacted traffic safety in the municipality. Specifically, Councillor Botterill has a stake in understanding how his motion to remove mobile photo radar has statistically impacted traffic safety in Sherwood Park, which is part of Strathcona County. This project sought to determine, as Chen and Warburton (2006) questioned, whether collision statistics "rebound" following the discontinuation of mobile photo radar programs (p. 675).

More broadly, other elected officials, administrators, and law enforcement officials have a collective interest in automated camera technology as a traffic safety tool. According to Strathcona County's (2014) *Traffic Safety Strategic Plan 2020*, the municipality "is committed to the proactive implementation of integrated, evidence-based and collaborative road safety strategies to create an increasingly safe and sustainable transportation environment" (p. i). This research provides evidence-based recommendations so the municipality can continue to make data-driven decisions and achieve its vision of having "no one seriously injured or killed while travelling on Strathcona County's road network" (Strathcona County, 2014, p. i).

1.2 Project Client

Strathcona County Councillor Brian Botterill is the project client. First elected to county council in 2010, Councillor Botterill represents residents and businesses in Ward 3, an urban area of Sherwood Park with significant traffic volumes (Strathcona County, 2016). Councillor Botterill has an interest in policing as well as traffic safety initiatives and tools. His political appointments include serving on the Strathcona County RCMP Community Advisory Board, which provides recommendations on policing enforcement priorities.

1.3 Project Objectives and Research Questions

The project's primary objective was to analyze how discontinuing mobile photo radar has affected traffic safety in Sherwood Park, including the frequency of fatalities, injuries, and property-damage-only collisions. The main research question was, "Does the presence of mobile photo radar have a significant impact on the number of vehicle collisions in Sherwood Park, Alberta?" This question was explored through statistical analysis of traffic collision data for 12 years (2001 to 2012), when mobile photo radar was operational, as well as 4 years (2012 to 2016) when it was removed from the municipality. During this 16-year period, over 17,000 observed collisions, injuries, and deaths were measured repeatedly for the population with and without the treatment condition of mobile photo radar. Additional data, including the number of mobile photo radar violations from 2001 to 2012, were collected, as were fine revenues during that period.

To assist with future research activities, a survey has been provided to the client to examine the public's perception and acceptance of mobile photo radar as a traffic enforcement tool. A paradox exists between statistical data on speed and its relationship to collision severity and the public's opinion about the risks of speeding when compared to other forms of dangerous driving. Motorists continue to exceed the posted speed limit, while at the same time acknowledging the risks of this behaviour. A survey helps elected officials, administration, and law enforcement understand public perception of mobile photo radar and its future use as a traffic safety tool.

In addressing the scope of the project, it should be noted that this was not a speed study and did not examine whether mobile photo radar is effective in lowering speeds. Further, the study did not assess the economic impacts of mobile photo radar and did not include a cost-benefit analysis of using automated camera technology compared to traditional traffic enforcement.

1.4 Organization of Report

This report is organized into eight sections, including this introduction. The second section, Background, provides general information on the history of photo radar, details on how the automated camera technology operates, the relationship between law enforcement and photo radar technology, an overview on where photo radar is operated in Canada, and a brief history on photo radar in Sherwood Park, Alberta.

Background is followed with a literature review covering subjects related to speed, collisions, safety effects of photo radar, limitations of photo radar, and issues related to accountability, transparency, and fairness of automated traffic enforcement, as well as leading automated enforcement practices from other jurisdictions. To assist with the understanding of the research problem, a conceptual framework and a logic model are included in this section to provide a graphical understanding between variables as well as a summary of key program elements and intended outcomes of mobile photo radar.

The fourth section, Methodology and Methods, includes an explanation of why an interrupted time series research design was used to compare traffic collisions, injuries, and fatalities in Sherwood Park, Alberta, over a 16-year time frame. In addition, the section covers analysis methods involving quantitative data supplied by Strathcona County (R. Anders, personal communication, April 10, 2017) through its Traffic Engineering and Safety Department's Traffic Crash Location System (TCLS). It concludes with a review of the project limitations and delimitations.

The final four sections—Findings, Discussion and Analysis, Recommendations, and Conclusion—present the findings, discuss and analyze them, make recommendations for the client and offer suggestions for future research, and provide a project summary.

2.0 Background

This section provides general background on the history of photo radar, details on how automated camera technology operates, the relationship between law enforcement and photo radar technology, an overview on where photo radar is operated in Canada, and a brief history of photo radar in Sherwood Park, Alberta.

2.1 History of Photo Radar

Photo radar began in Holland, where in 1964, a Dutch company created the first speed camera (Gatso USA, n.d.). Originally, the technology was not designed for traffic enforcement purposes but to measure a rally car driver’s speed on a racetrack. The invention of the Gatsonides would later become known as the world’s first reliable speed measuring device (Gatso USA, n.d.).
In the 1970s, speed enforcement cameras evolved in Europe with Germany becoming one the first countries to adopt automated speed-detection technology (Delaney et al., 2005, p. 406). With the advent of digital camera technology, photo radar continued to expand throughout the 1990s (Askland, 2013, p. 1), with Great Britain amending its Road Traffic Act in 1991 so courts could accept evidence of speeding from approved cameras (Delaney et al., 2005, p. 409).

Over the past 50 years, more than 40 countries have used automated speed enforcement systems to enforce traffic laws (Hajbabaie, Medina, Wang, Benekohal, & Chitturi, 2011, p. 118). Although Europe pioneered the technology, photo radar is used in Canada (Chen, 2005; Vanlaar, Robertson, & Marcoux, 2014), Australia (Delaney et al., 2005; Tay, 2009), and a number of European countries (Delaney et al., 2005; Elvik, 2001; Gains, Shrewsbury, & Robertson, 2004; Goldenbeld & van Schagen, 2005; Pilkington, 2003).

Historical use of speed cameras in the United States is more limited due to its relatively recent introduction as a form of automated speed enforcement. A small number of American municipalities have been using photo radar for a significant period of time (Retting, Farmer, & McCartt, 2008, p. 441). Even without widespread use in the United States, photo radar is the most widely used form of automated traffic enforcement technology in the world today (Institute for Highway Safety, 2004).

2.2 How Photo Radar Works

Generally, governments respond to speeding by imposing legal limits on traffic speed on the roads. Wilson et al. (2006) stated that speed limits are used to regulate traffic speed and promote road safety by establishing an upper limit on speed and reducing the variances of vehicle speeds, also known as dispersion (p. 3). The effects of such legislation are well researched and documented (Chen, Wilson, Meckle, & Cooper, 2000, p. 519; Chen & Warburton, 2006, p. 662; Goldenbeld & van Schagen, 2005, p. 1135; Retting et al., 2008, pp. 440–441; Tay, 2009, p. 178; Wilson et al., 2006, p. 3).

Even with the advent of photo radar, the most conventional method of speed detection and enforcement continues to be the deployment of police officers using radar and laser equipment to identify and ticket violators (Delaney et al., 2005, p. 404). This system is based on a specific deterrence model, which Tay (2009) described as the apprehension and sanction of errant motorists (p. 179). Punishment or reinforcement is direct as the police officer immediately issues a ticket or warning to the motorist at or near the location of the violation.

A major difference between police officers issuing tickets and photo radar is the general deterrence model of enforcement. Ross (1982) explained general deterrence as "the effect of threatened punishment on the population in general, influencing potential violators to refrain from a prohibited act through a desire to avoid consequences" (p. 118). Automated enforcement produces a general deterrent effect since the technology can be more widely deployed and create a broader enforcement area (Tay, 2009, p. 179). Operationally, the number of photo radar units is relatively small compared to the kilometres of roads requiring enforcement, so it is important to promote a perception of widespread automated speed camera use to establish a general deterrence effect.

Generally, photo radar is a supplement and not a replacement for traditional traffic enforcement. To increase public safety and reduce the frequency of traffic collisions, many countries, states, and provinces legislate some form of speed camera program. Automated cameras monitor traffic speeds and photograph vehicles travelling above specified levels that are higher than the posted speed limit (Retting et al., 2008, p. 440). In Alberta, a list of accepted photo radar technology includes radar, laser and LIDAR (light from a laser), and time-over-distance measuring devices using imbedded road loops (Province of Alberta, 2014, p. 6).

The most common methods for deploying automated enforcement involve cameras that move to various locations and fixed cameras that monitor speeds at specific locations. Mobile cameras are usually accompanied by enforcement personnel while fixed cameras are not. In Alberta, photo radar must have a human operator on site unless the Government of Alberta issues an exemption for areas of special needs or other exceptional circumstances (Province of Alberta, 2014, p. 3). This exemption does not apply to intersections or fixed-camera locations.

When it comes to the operation of mobile photo radar, a radar beam or laser detects a vehicle as it enters an enforcement zone and captures its speed. As it leaves the zone, the end of the vehicle is detected, and if that vehicle's speed exceeds the posted speed limit for that location, the system sets off an alarm and takes a photo of the vehicle (Calgary Police Service, 2016). When the photo is taken, it is often accompanied by a camera flash to enhance the image of the license plate. The camera information is downloaded, and the registered owner of the vehicle is issued a ticket in the mail. In the case of automated enforcement, the license plate holder rather than the driver is held responsible for the speed offense since the driver's identity is difficult to prove in the photograph. The exception is when a vehicle is ticketed for going over 50 km/hr above the posted speed limit. In this case, the vehicle's registered owner receives a mandatory court summons (Province of Alberta, 2014).

Mobile photo radar is often mounted inside an unmarked police vehicle, initially making it difficult for motorists to identify the vehicle as a traffic enforcement tool. The vehicle is parked in visible and hidden locations, and, typically, the mobile speed camera unit is noticed only after traffic has passed it. It should be noted, however, that most police vehicles operating photo radar, even if they are unmarked, become recognizable to motorists over time. The type of vehicle used, its location, and the effects on traffic flow around the unmarked vehicle eventually attract the public's attention (Tay, 2010, p. 251). Romer, Trombka, and Downie (2009) added, "Data suggests that drivers adjust their speeds in known automated enforcement areas whether or not camera equipment is permanently visible" (p. 71).

When it comes to selecting automated speed enforcement locations, the province of Alberta requires each location to have a site assessment document issued by the jurisdiction's police service to show why the area was chosen and how it relates to traffic safety. This document must be refreshed every 3 years for speed locations (Province of Alberta, 2014, p. 1).

2.3 Police and Photo Radar

Traditionally, speed enforcement relies heavily on the presence of police officers who issue tickets to motorists driving above the posted speed limit. This model of specific deterrence works best if enforcement agencies have sufficient resources to mount a range of speed detection programs. In other words, enforcement of speed limits must be widespread to ensure that drivers believe that if they speed, they will be caught by police officers.

The enforcement reality is that police officers cannot be present on all roads all the time. Mobile photo radar is generally more cost effective than police officers conducting traffic patrols and enables active enforcement at more locations (Tay, 2009, p. 185). Police rely on photo radar technology because traditional enforcement may not be enough to curb violations. Even on dedicated traffic patrols, police officers can observe only a finite number of violators and write tickets. The main limitation of this enforcement model is staffing. Drivers know the risk of being detected is small when the only enforcement tool is police officers (Institute for Highway Safety, 2004).

Unlike police officers, speed cameras can be placed in many locations around the clock and capture virtually every violator. This creates a form of general deterrence since motorists are discouraged from violating the speed limit because the risk of detection increases when cameras are in widespread use (Institute for Highway Safety, 2004).

Another benefit of mobile photo radar for police officers is safety. In congested areas, there may be no safe location to pull over a speeding vehicle (Delaney et al., 2005, p. 404). It may be difficult to observe speeds at certain times and locations, or alternatively, police officers may be diverted to other enforcement priorities despite a need to monitor and enforce traffic safety.

2.4 Canadian Provinces and Photo Radar

Figure 1 illustrates provincial laws permitting and forbidding the use of mobile photo radar throughout Canada.

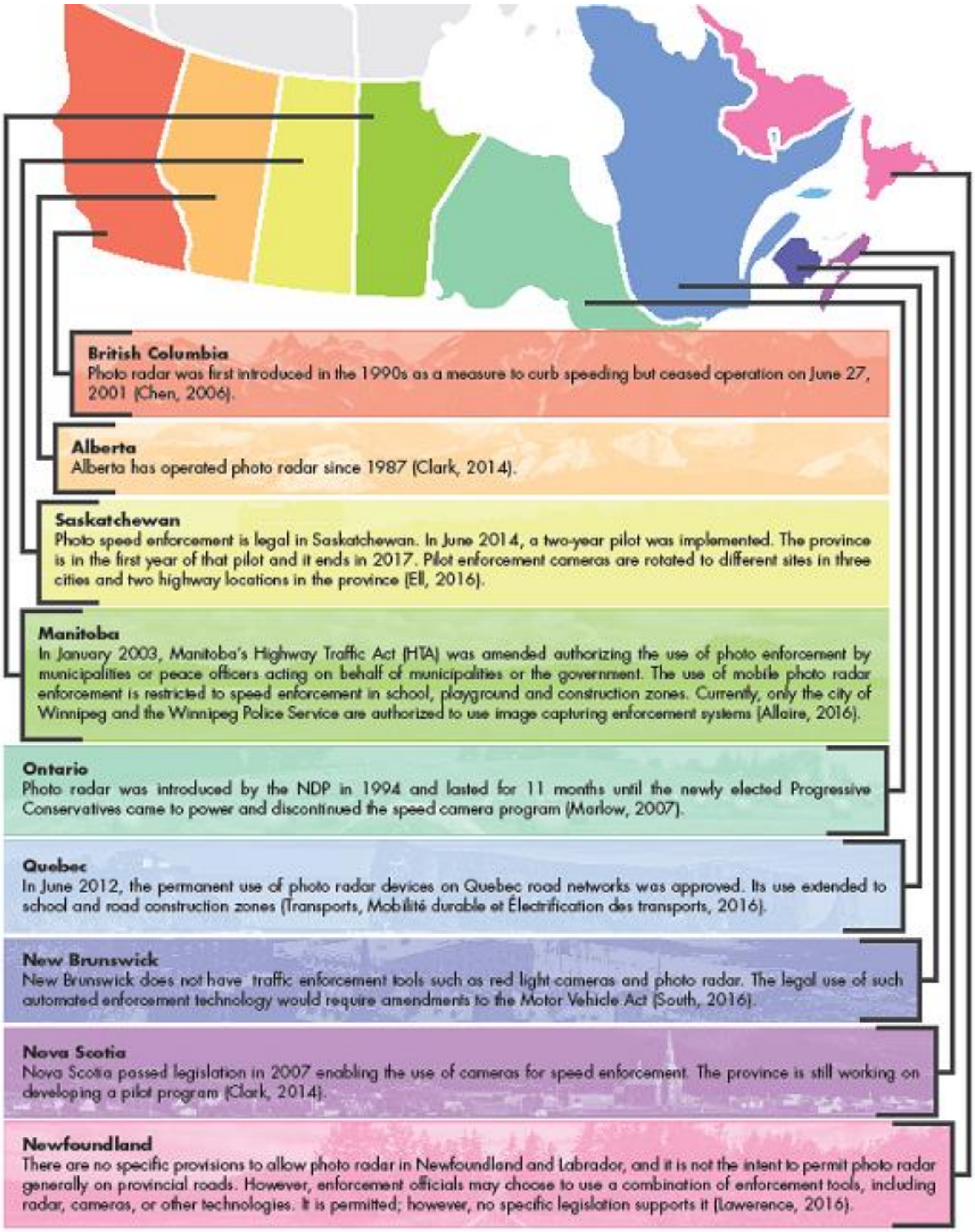

Figure 1. Canadian provinces and photo radar.

Note. Sources in Figure 1 cited from personal communication include N. Allaire, May 10, 2016; S. Ell, May 9, 2016; and J. Lawrence, May 13, 2016. These were email communications, which can be provided upon request.

2.5 Sherwood Park and Mobile Photo Radar

Strathcona County is a unique specialized municipality located east of Edmonton, Alberta, Canada, consisting of a large urban service area known as Sherwood Park surrounded by smaller hamlets, a large industrial zone, and rural areas. According to the 2015 census, Sherwood Park has a population of 68,782 (Strathcona County, 2016), although it is technically classified as a hamlet since it is part of the specialized municipality.

The specialized municipality classification means the Province of Alberta, for programs and grants purposes, recognizes Sherwood Park and the Urban Service Area immediately around it as equivalent to a city, while rural Strathcona County is recognized as equivalent to a municipal district (Strathcona County, 2016). This is a critical distinction since photo radar enforcement, including red light cameras, fixed intersection speed detection cameras, and mobile photo radar cameras, are utilized only within the Urban Services Area of Sherwood Park and not in any of the rural areas or other hamlets in the municipality (Strathcona County, 2015). In addition, the province of Alberta prohibits the use of automated speed enforcement on provincial highways (Province of Alberta, 2014, p. 1).

Strathcona County operated mobile photo radar in Sherwood Park from 1997 until August 31, 2012. Initially, peace officers used unmarked vehicles on or near public roadways to take photographs of vehicles exceeding the posted speed limit and issue traffic tickets to the registered vehicle owner in the mail (Strathcona County, 2011b). As technology advanced, new forms of mobile photo radar became available. In 2011, Strathcona County began using a stand-alone device box, which did not require a vehicle to operate it (Strathcona County, 2011b). The speed camera device box resembled a standard utility box and could be easily disguised when it was in operation. The unit did require an operator within a few hundred feet to monitor the device through a remote terminal.

Based on the *Traffic Safety Strategic Plan 2020*, Strathcona County (2014) has seen some improvements in traffic safety; however, there were still over 21,500 reported collisions in the municipality between 2004 and 2013 with 73 people having lost their lives and 315 suffering major injuries (p. 1).

Between 2009 and 2012, 75,035 mobile photo radar tickets were issued in Sherwood Park, accounting for a significant amount of revenue for the municipality (J. Peebles, personal communication, October 30, 2016). When the speed camera device box was introduced, the municipality’s revenue from mobile photo radar jumped nearly $700,000 over the previous year, making it the largest single revenue increase within a 4-year period (J. Peebles, personal communication, October 30, 2016). Table 1 shows the 4-year revenue.

Table 1.
Strathcona County Photo Radar Revenue 2009 to 2012

Year	2009	2010	2011	2012
Revenue	$1,515,092	$1,573,080	$1,905,233	$2,595,443

Note. Information in the table is based on personal communication with J. Peebles, October 30, 2016.

The new speed camera device box, the times and locations of automated enforcement activities, and the question of whether mobile photo radar was being utilized as a traffic safety tool or a source of revenue generation spawned significant political and policy pressures for elected officials. In response, Councillor Brian Botterill made a motion on September 13, 2011, to cease operation of mobile speed cameras (Strathcona County, 2011a). Discontinuing photo radar was a contentious issue. Councillor Botterill argued, “Photo radar has never caught a drunk driver; it’s never caught a stolen car; it’s never caught someone driving without a license; it’s never taken someone’s license for excessive speeding” (as cited in CBC, 2011, para. 2). Opponents of the ban, including RCMP Inspector Gary Steinke, countered, “Photo radar is a tool. It enables us to enforce speed limits in the county” (as cited in Baxter, 2011, para. 13). It took Strathcona County Council nearly three hours to debate the merits of discontinuing mobile photo radar. In the end, the motion was approved by the narrowest of political margins—5 votes to 4 (CBC, 2011), and mobile speed cameras were removed from the municipality beginning in August 2012.

2.6 Traffic Crash Data Collection, Analysis, and Management Program

Strathcona County collects and manages traffic collision information through a database system known as the Traffic Crash Location System (TCLS). Although TCLS is relatively new, having been introduced in 2013, collision data dating back to 1982 has been uploaded into the system (Strathcona County, 2014, p. 19).

As shown in Figure 2, the TCLS database requires cooperation and partnership between the RCMP and Strathcona County. The RCMP supply Strathcona County with collision reports, which are entered into the system by a part-time administrative position in the Transportation and Agricultural Services Department (Strathcona County, 2014, p. 19). TCLS allows the municipality to make data-driven decisions to improve overall road safety throughout the municipality.

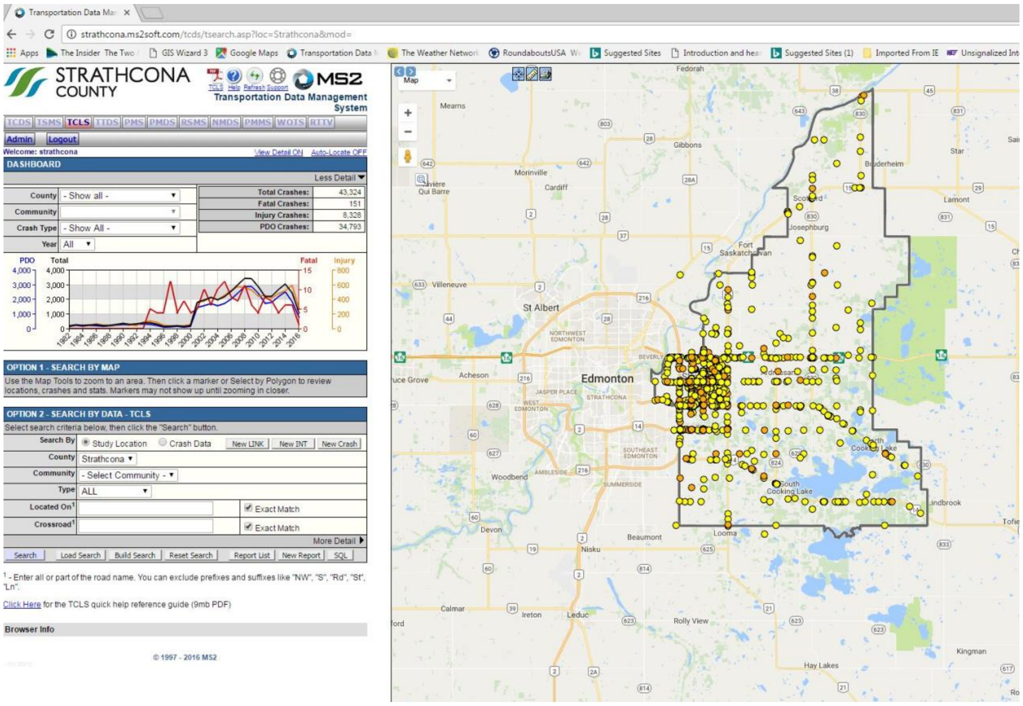

Figure 2. Strathcona County Traffic Crash Location System (TCLS).

Note. The figure was provided in a personal communication with R. Anders on November 22, 2016.

2.7 Summary

Photo radar is one of the oldest and most widely used forms of automated enforcement technology. As an enforcement tool, the technology tends to supplement and not replace traditional police traffic officers, who are limited to the number of roads that can be monitored at any given time.

Photo radar possesses several tactical advantages. Police officers can issue a finite number of tickets during a shift, while photo radar technology can capture nearly all speed violations over an extended period of time. Camera technology can also be placed in locations deemed too congested or dangerous to pull over a speeding motorist using police traffic officers. When in use, mobile photo radar creates a form of general deterrence where motorists are discouraged from speeding because a fixed or mobile camera can be placed in nearly any location for traffic enforcement.

In Canada, the experience with photo radar is varied. Some provinces, such as British Columbia and Ontario, operated and then subsequently discontinued photo radar programs. Other provincial jurisdictions, like Alberta, have used photo radar for an extended period of time, while Saskatchewan and Quebec have been the most recent provincial jurisdictions to implement the technology as an enforcement tool. Overall, photo radar has not been universally adopted by Canadian provinces.

In Sherwood Park, Alberta, photo radar operated from 1997 to August 31, 2012. Between 2009 and 2012, there were 75,035 mobile photo radar tickets issued in the municipality (J. Peebles, personal communication, October 30, 2016). The volume of tickets issued, along with the addition of a new mobile photo radar unit disguised as an electrical box, placed significant public pressure on elected officials to discontinue the enforcement program. On September 13, 2011, Strathcona County Council voted and made the decision to eliminate mobile photo radar. Since then, there have been questions about how the removal of photo radar has impacted traffic safety in the municipality.

The majority of municipalities surrounding Strathcona County operate some form of automated enforcement technology and have active mobile photo radar programs. More broadly, many other countries and states have utilized automated camera technology to reduce traffic collisions, injuries, and deaths. Literature and research from other jurisdictions provide additional context as to whether mobile photo radar is a suitable and effective tool to reduce speeds, save lives, and prevent minor and major injuries.

3.0 Literature Review

3.1 Introduction

This chapter provides a systematic review of current literature on automated speed enforcement. The review uses an intellectual historical approach, which Yang and Miller (2008) called "the history of scholarship in a given area" (p. 63). Considered another way, it is an approach that involves understanding how a particular group of researchers and scholars have conducted research on a specific subject.

Mobile photo radar involves many components and areas of research. As such, it was necessary to divide the research into specific sections to allow for a more orderly examination of current literature on the subject of automated traffic enforcement in general and mobile photo radar specifically. First, speed and collisions, the catalyst for traffic enforcement programs, are reviewed. This is followed by an assessment of photo radar studies and an exploration of the safety benefits and limitations of such programs. The section concludes with a review on abstract concepts such as fairness, accountability, and transparency and how they apply to the operation, evaluation, and public acceptance of mobile photo radar.

To conduct the literature review, keyword search terms were used, and they included *mobile photo radar*, *photo radar*, *speed enforcement*, and *automated camera enforcement*. This information was accessed using the ScienceDirect, Environmental Index, and EBSCOhost research databases. Although there is significant grey literature involving photo radar effects on traffic safety, efforts were made to find scientific and peer-reviewed journals. The journals judged to be most important included the *Journal of the Transportation Research Board*, *Traffic Injury Prevention*, *Journal of Policy Analysis and Management*, *Accident Analysis and Prevention*, *Journal of Public Health Policy, American Journal of Public Health*, and *British Media Journal*. Primarily, articles published in these journals between 2005 and 2015 were examined.

3.2 Speed

Although many factors contribute to traffic collisions, speeding is accepted as a major cause of property damage, injuries, and fatalities (Kelly, 2005, p. 416; Tay, 2009, p. 178; 2010, p. 248). A sizeable body of literature exists that convincingly demonstrates the relationship between speed and the severity of collisions (Elvik et al., 2005, p. 48; Evans, 2004a, p. 1; Goldenbeld & van Schagen, 2005, p. 1135; Kelly, 2005, p. 416; Redelmeier & Bayoumi, 2010, p. 15). Speed is clearly related to collision severity by basic mechanical laws. During a collision, the faster a vehicle is travelling, the greater the energy absorbed by the occupants when a rapid change in velocity occurs.

When it comes to speed, injury severity increases nonlinearly. Reducing the fastest speeding behaviour will have a direct impact on the number of serious collisions (Tay, 2009, p. 28). Wilson et al. (2006) further asserted that curbing top-end speeders, the ones who speed the fastest, should reduce the number of deaths and severe injuries in collisions (p. 3).

A paradox exists when it comes to speeding and collisions. Researchers consistently show speeding to be a major determinant of traffic collisions, yet many Canadians ranked speeding as the least dangerous driving situation (EKOS Research Associates Inc. [EKOS], 2005). Other factors, such as impaired driving, following too closely, changing lanes abruptly, and driving in snowstorms ranked higher than speed in terms of driving risk factors. The situation is even more acute in Alberta, where motorists consider driver inattentiveness to be the single greatest contributor to crashes and not speeding (EKOS, 2005, p. 12).

Although there is ample evidence about the risk of speeding, many motorists choose to drive above the posted speed limit. One of the challenges facing policymakers and law enforcement is that speeding does not have a universal definition. Speeding is an elastic term and tends to be defined in a number of ways. Technical speeding is any speed above the posted limit, relative speeding is perceived as a safely exceeded speed that depends on driving circumstances such as road conditions, and absolute speeding is driving behaviour that exceeds the posted limit by 10 or more percent (EKOS, 2005, p. 45). The reality with speeding is that many motorists know that they may be technically speeding, but they do not believe they are driving in a way that endangers themselves or others. There is a perception with Canadian drivers that the speed they travel does not significantly increase their risk of an accident, or that if it does, the overall risk profile is very low (EKOS, 2005, p. 45).

EKOS's (2005) findings are similar to those found in Strathcona County's (2015) *Traffic Safety Survey* results, which involved a telephone survey of 500 Strathcona County residents. When asked how fast one should drive on a main road in Strathcona County, over half reported the posted speed limit. However, many believed that driving 5 km/h or 10 km/h over the posted limit was still safe (Strathcona County, 2015, p. 2).

When it comes to speeding, prevailing attitudes exist where many motorists believe they are not driving in a way that endangers themselves or others. A research poll found that of those who admit to speeding, 57% are likely to do so because they do not want to be late, 51% because they believe the speed limits are set too low, or 51% because they are not paying attention to the speed at which they are driving (EKOS, 2005, p. ii).

A gap exists between statistical data on speed and its relationship to collision severity and the public's opinion about the risks of speeding when compared to other forms of dangerous driving. This requires governments to continue examining how best to regulate, monitor, and enforce speed limits to reduce the frequency and severity of collisions.

3.3 Collisions

Road traffic collisions are the eighth leading cause of death globally and the leading cause of death for young people aged 15 to 29. More than a million people die each year on the world's roads, and the cost of dealing with the consequences of these road traffic crashes is billions of dollars (World Health Organization, 2013, p. vii).

There are two basic types of collisions: single and multiple vehicles. In a single vehicle collision, the rate of speed correlates to the risk of crashing (Kelly, 2005, p. 416). Evans (2004a) reported that a 1% increase in speed raises the fatality risk by 4 to 12% (p. 1). The risk of injuries or fatalities from speeding is even greater in traffic. Wilson et al. (2006) found that the higher the deviation in speed from the average, the greater the risk of a traffic collision (p. 3), since travelling at different speeds increases the number of interactions between vehicles. Whether it is a single or multiple vehicle collision, speed is a leading cause of fatalities and injuries in Alberta. In 2014, one in four Alberta drivers in a fatal collision and one in 10 Alberta drivers in injury crashes were determined to be driving at an unsafe speed (Alberta Transportation, 2015, p. 5).

Although speeding is considered to be a major determinant in traffic collisions (Evans, 2004b, p. 1; Tay, 2009, p. 178; 2010, p. 1), numerous others factors contribute to injuries and fatalities on roads. Failure to obey traffic rules, overburdened road systems, overcapacity hauling by public and transport vehicles, poor vehicle maintenance, distracted driving, impaired driving, driver fatigue, following too closely to other vehicles, changing lanes abruptly and weather conditions, among other factors, all contribute to the total number and severity of collisions. For example, impaired driving is one of the leading causes of collisions in developed countries. Gopalakrishnan's (2012) research on road traffic safety and public health showed that nearly 20% of drivers who are killed in traffic collisions have alcohol in their blood in excess of the legal limit (p. 144).

A 2016 study that utilized cameras and sensors in vehicles showed that speed is one of many factors that result in a vehicle collision (Dingus et al., 2016). Operating a vehicle while angry, sad, or agitated is more likely to result in a crash than speeding. The same is true for making right-of-way errors, sudden or improper braking or stopping, and being unfamiliar with a vehicle or roadway (Dingus et al., 2016, p. 2641). It appears speeding may not be the main catalyst of vehicle crashes.

Researchers have indicated that the number of lives lost in road accidents, at least in developed or high-income countries, has trended downwards in recent decades (Gopalakrishnan, 2012, p. 144). This is consistent with statistical data from Transport Canada (2014), which shows serious injuries have dropped to 9,647 in 2014, a decline of 9.5% from 2013 (p. 2). The same is true for fatalities, which saw a 6% reduction from 2013, with 1,834 deaths in 2014 (Transport Canada, 2014, p. 2). In fact, 2014 saw a decrease in all fatality, serious injury, and total injury categories, marking the lowest count since data collection began in the 1970s. Even the number of fatalities per billion kilometres travelled is the lowest on record (Transport Canada, 2014, p. 2).

Road injury and fatality reductions are a Canadian public health success story. The Public Health Agency of Canada (PHAC) has attributed sustained road safety efforts over the last few decades as responsible for preventing thousands of injuries and deaths (Public Health Agency of Canada [PHAC], 2012, p. 11). Today, more Canadians are wearing seatbelts and child restraints (PHAC, 2012, p. 28), and vehicles are equipped with more safety technology to save lives and prevent injuries. PHAC (2012) did not list mobile photo radar as one of the reasons for prevention of fatalities and injuries.

Although considerable success in reducing traffic collisions and their consequences has been achieved, motor vehicle crashes remain a leading cause of death and injury for Canadians of all ages, especially for young adults (PHAC, 2012, p. 9). In Canada, provincial and federal governments continue to use public education campaigns, adopt new traffic safety policies and legislation, and explore a variety of enforcement tools, including photo radar, in a concerted effort to reduce the frequency and severity of traffic collisions.

3.4 Photo Radar Studies

There is no shortage of photo radar studies. The studies range from fixed photo radar to mobile photo radar and have been conducted in a variety of urban and rural locations in Canada (Chen et al., 2000; Vanlaar et al., 2014), Australia (Delaney et al., 2005; Tay, 2009), and a number of countries in Europe (Delaney et al., 2005; Elvik, 2001; Gains et al., 2004; Goldenbeld & van Schagen, 2005; Pilkington, 2003).

These studies are inherently difficult to summarize due to heterogeneity issues. There is a wide variation on types of photo radar interventions, length of follow-up periods, setting and number of interventions, outcome measures, and control sites. Wilson et al. (2006) conducted a systematic review of photo radar studies and found many to be lacking “methodological rigor” (p. 27). Most studies controlled for or described only a few factors that contribute to traffic collisions, including seasonality, time of day, changes in road design, speed limits, levels of road safety publicity, and traffic volumes. For example, when it comes to traffic volumes, Romer et al. (2009) found an increase or decrease in the number of vehicles travelling along a road could explain, in part, variations in rate of speed camera violations or collisions (p. 75).

Methodologically, the quality of most photo radar research studies is generally poor. A randomized control trial is the gold standard of experimental research as it provides the highest hierarchy of evidence when it comes to measuring the effectiveness of interventions on a treatment group. No studies were identified that used this type of design to evaluate photo radar (Pilkington & Kinra, 2005, p. 331; Wilson et al., 2006, p. 19). Instead, photo radar studies trend towards observational and quasi-experimental designs, where the adequacy and appropriateness of comparison and control areas of enforcement are questionable.

Making methodological matters worse, Wilson et al. (2006) observed that most studies do not have adequate control or discussion of potential confounders, including regression to the mean, long-term trends in crash rates, and changes to traffic volume (p. 27). As Chen et al. (2000 confirmed, “Among the reported studies, most did not apply rigorous research designs and the majority were limited to pre-post designs without controls for other factors” (p. 518).
Indeed, the lack of randomized controlled trials makes it difficult to attribute any change in traffic collisions, injuries, and fatalities to the photo radar intervention. Any number of factors could result in an underestimate or overestimate of the efficacy of mobile photo radar (Pilkington & Kinra, 2005, p. 334). Factors such as traffic calming and engineering efforts, including the narrowing of roads, speed humps, vehicle registrations, education campaigns, improvements in car safety technology, and seasonal weather patterns can influence the frequency and severity of road crashes.

Considering photo radar's lengthy operational history, it is perplexing as to why randomized controlled trials have not been utilized in past studies. Wilson et al. (2006) provided a possible explanation in that "it may be considered difficult to ethically randomize interventions to some traffic hotspots and not to others, when the intervention is expected to be worthwhile" (p. 27). Even without randomized control trials, the need for more rigorous and higher quality studies of speed detection technology is clear. Although a systematic review of studies appears to conclude that photo radar does, in fact, reduce traffic collisions and related road injuries and deaths (Delaney et al., 2005, p. 412), the present body of knowledge requires a stronger evidence base to solidify claims about the effectiveness of automated speed enforcement.

3.5 Safety Benefits of Photo Radar

While randomized control studies do not appear in the literature, several other researchers have examined the safety effectiveness of photo radar interventions (Delaney et al., 2005, p. 3; Goldenbeld & van Schagen, 2005, p. 1135). Most of the studies involved fixed cameras measuring speeds at intersections and not mobile photo radar. Goldenbeld and van Schagen (2005) found that despite the location differences between fixed and mobile speed detection cameras, the safety benefits attributed to the technology are comparable (p. 1136).

Of the mobile photo radar studies available (Chen et al., 2000, p. 517; Gains et al., 2004, p. 2; Goldenbeld & van Schagen, 2005, p. 1135; Keall, Povey, & Frith, 2001, p. 277; Tay, 2010, p. 254), they showed a variable range of reported reductions in collisions, injuries, and fatalities. In Canada, Chen et al. (2000) measured the effects of mobile cameras along provincial highways and reported an 11% reduction in injuries and a 17% reduction in fatalities (p. 526). Another rural road evaluation of the British Safety Camera Program by Gains et al. (2004) involving mobile speed enforcement reported a 51% reduction in the number of traffic injuries (p. 6). A study in the Netherlands by Goldenbeld and van Schagen (2005) found similar reductions of 21% in the number of injury collisions and causalities (p. 1135). Even though injury and collision reductions appear significant, the results should be viewed with hesitation. When it comes to evaluating the success of mobile photo radar, the application of road engineering measures, additional enforcement efforts, and development of improved traffic flows can influence findings unless variables are controlled for in the study. Without controlling for confounders, the actual effect of mobile photo radar may be much larger or smaller than reported.

Several researchers (Chen & Warburton, 2006, p. 662; Hajbabaie et al., 2011, p. 118; Retting et al., 2005, p. 444; Romer et al., 2009, p. 71) reported a spillover or halo effect that reduces traffic speeds and may help to explain the wide range of results in how mobile photo radar reduces collisions, injuries, and fatalities. Hajbabaie et al. (2011) noted how speed reductions continue even after the removal of photo radar, creating a so-called "halo enforcement effect over an extended area" (p. 125). When studying the effects of mobile speed cameras in Montgomery County, located in the state of Maryland, Romer et al. (2009) found similar results with data suggesting that motorists adjust their speeds in known automated enforcement areas whether or not speed cameras are visible (p. 440). In British Columbia, a photo radar program reduced traffic speeds at enforcement or treatment areas and at non-enforcement locations, lowering the number of collisions, injuries, and fatalities (Chen & Warburton, 2006, p. 661). Zaal (1994) considered the spillover effect found in automated speed detection devices to be a key safety advantage over traditional police enforcement (p. ix).

A study by Tay (2010) took a different approach when evaluating the effects of mobile photo radar on injuries in Edmonton, Alberta. His research identified a correlation between the number of registered drivers who receive mobile photo radar tickets and the number of injury collisions per month. Tay (2010) reported that the higher the number of tickets issued, the fewer injury crashes occurred in the city. Tay (2010) went as far as saying, “Injury crashes can be further reduced by devoting more resources to the current speed camera programme” (p. 254).

The question remains as to whether mobile photo radar is more effective than traditional police officer deployment to increase traffic safety. The City of Edmonton (2016) and the City of Ottawa (2016) boast similar populations. One of the major traffic enforcement differences between the two cities is that Edmonton operates a mobile photo radar program and Ottawa does not. Despite issuing 12 times more speeding tickets than Ottawa, Edmonton has a higher average fatality rate and collision rate per 100,000 people when compared from 2011 to 2014 (FairAlbertaRoads, n.d.). In this example, one city with mobile photo radar has far higher rates of fatalities and injuries than a comparable municipality that does not operate automated speed detection devices. This discrepancy reinforces the notion that photo radar may be less effective in preventing traffic collisions than some research has suggested.

3.6 Limitations of Photo Radar

Despite evidence that speed cameras are an effective safety intervention, they are frequently subjected to public and political scrutiny regarding their operation, application, and performance when compared to traditional traffic enforcement by police. When a motorist is pulled over by a police officer for speeding, punishment is assumed to be swift as the ticket or warning is issued on the spot. Tay (2009) considered celerity or swiftness one of the key components of deterrence (p. 179). Unlike those from a police officer, offenses captured by photo radar arrive days or even weeks after the violation has occurred.

A frequently cited complaint of mobile photo radar is it that does not stop the violations it records (Askland, 2013, p. 7). A speed camera simply photographs a violation, but it cannot intervene to apprehend the motorist in question. Critics have listed driving offenses that photo radar cannot address, including dangerous, intoxicated, or erratic driving behaviours (FairAlbertaRoads, n.d.; “Petition calls,” 2014; Pearson, 2016). These are the types of events an on-the-scene police officer would be able to observe and have the discretion to enforce.

In a study on the effectiveness of automated and manned traffic enforcement using data from the Australian State of Queensland, Tay (2009) found no statistical benefit of adding automated enforcement to traditional police officer enforcement (p. 184). Further, Tay (2009) revealed that regular traffic enforcement had a significant effect in reducing the number and severity of collisions per month while automated enforcement had a marginal effect in reducing the total number of crashes (p. 185).

Explaining this phenomenon requires an understanding of the difference between general and specific deterrence. Speed cameras capture all violators and cannot differentiate between motorists (general deterrence), whereas traditional police enforcement tends to target drivers who are at a much higher risk of speeding and causing a severe traffic collision (specific deterrence). Tay (2009) found that traditional speed enforcement by police officers yielded a larger share of young male drivers who were issued speeding tickets when compared with automated enforcement (p. 182). In Alberta, the specific deterrence may work more effectively than a general deterrence approach, since casualty rates were highest for persons between the ages of 15 and 24, and male drivers between the ages of 18 and 19 had the highest rate of fatalities (Alberta Transportation, 2015, p. 4).

Strathcona County's *2015 Traffic Safety Survey* found males were most likely to report it was safe to drive faster than the posted speed limit. Over 20% of males said it was safe to travel more than 10 km/h over the limit, while 2.8% indicated 15 km/h over the posted limit was a safe driving speed (Strathcona County, 2015, p. 9). By targeting motorists with the highest traffic safety risk factors and greatest propensity for speeding, police officers may reduce the number and severity of traffic collisions by providing a form of specific deterrence.

Some photo radar opponents concede speed cameras may lower speeds, but at the expense of safe driving practices. Mobile photo radar is often hidden behind trees, an overpass, or any structure so enforcement cannot be seen (FairAlbertaRoads, n.d.). A motorist approaching a speed camera may focus extra attention to the speedometer and less attention to the road ahead. Potentially, this may lead to an increase in rear-end collisions when drivers suddenly slow down as they approach mobile photo radar (Smith, 2004). A 2016 study highlighted that improper braking and stopping was a greater risk factor for collisions than speeding (Dingus et al., 2016, p. 2641).

It can be distracting and dangerous when motorists are looking at the sides of the road for photo radar vehicles or devices. In the *Road Injury Prevention and Litigation Journal*, electronic traffic display boards, which flash speeds of oncoming vehicles, were found to be more effective at reducing vehicle speeds than photo radar (TranSafety Inc., 1998). The display boards also provide the added benefit of having motorists looking ahead at traffic and not below at their speedometer or the sides of the roads for automated camera enforcement devices.

While mobile photo radar appears to offer certain safety benefits, it is not without limitations. Literature is inconclusive as to whether automated enforcement is more effective than traditional police officers since speed cameras do not apprehend motorists who may be impaired, distracted, or driving recklessly. Based on a general deterrence model, mobile photo radar cannot specifically target motorists with the highest risk of causing a serious road crash. In addition, photo radar vehicles and devices may distract motorists, increasing the frequency of rear-end collisions when drivers suddenly or unexpectedly slow down.

3.7 Fairness, Accountability, and Transparency

When speed cameras are introduced or used, public and political controversy quickly follows. Delaney et al. (2005) went as far as to say photo radar is controversial wherever used (p. 404). There is widespread public concern over operational fairness (Pursaga, 2013; Staples, 2015b), accountability (Gunter, 2016; Lee, 2016), and transparency (Kent, 2014a). According to Askland (2013), public response to photo radar, particularly its widespread use, is generally negative. Some of the negativity has to do with attitudes and perceptions of speeding, but most relate to the use of cameras for revenue generation (Askland, 2013, p. 2). Opponents question whether cameras are unfair due to factors such as failure to identify the driver, failure to notify the offender on the spot, lack of witnesses to the offense, and the lack of opportunity to explain circumstances of the event at or near the location of the violation to a police officer (Delaney et al., 2005, p. 405).

Complaints about fairness are still in the minority when compared to concerns over mobile photo radar's propensity to generate fine revenue. Photo radar has been called "greasy" (Staples, 2015a, para. 2), a "cash-grab" (Dawson, 2016, para. 1; O'Farrell, 2013, para. 3; Ramsay, 2014, para. 14) "predatory" (Gandia, 2014, para. 5), and a "roadside photo fundraiser" (Gunter, 2016, para. 3) by its critics. Admittedly, these terms are used to generate controversy about the technology and to create public and policy suspicion about its intended use.

There is evidence suggesting that speed cameras' revenue and not public safety is the primary objective of mobile photo radar activities (Staples, 2016a). In larger municipalities, photo radar does not generate thousands of dollars in revenue but tens of millions of dollars (Staples, 2015a). Although some officials acknowledged a revenue motive for the increased use of photo radar, many government officials stress the promotion of public safety to justify photo radar enforcement. Askland (2013) posited that this reaction is in response to a sharp expression of public concern about revenue-inspired enforcement (p. 2). Wilson et al. (2006) suggested that automatic speed enforcement has the capability of being a substantial net revenue-raising activity thus blurring "the line for the public as to whether governments use the device for safety or for fiscal reasons, and may harden attitudes towards their use" (p. 3).

In his article, *Meet the Hinton honey pot, king of Alberta speed traps*, Staples (2016a) revealed a mobile photo radar location in Hinton, Alberta, that generated 70% of the community's entire photo radar revenue, approximately $1.7 million in a single year. According to Stuart Taylor, an elected official in Hinton, the photo radar site has a marginal safety risk and is not located in a high collision location (Staples, 2016a). In this single enforcement spot, Global Traffic Group was generating $8,000 to $9,000 per hour from the site, as opposed to $200 to $300 per hour if it was set up in a school zone (Staples, 2016a).

In two of Alberta's largest municipalities, Edmonton and Calgary, concerns exist that they have become financially dependent on photo radar revenue. When the photo radar program was introduced in Edmonton in 1993, it was touted as an accurate and effective means of traffic enforcement (Tay, 2010, p. 249). Today, the photo radar program generates a significant amount of revenue for the city, which is being used to offset the rise in municipal spending (Kent, 2014b). When the City of Edmonton took over photo radar operations from a contractor, the number of tickets issued to motorists increased by 159% or 259,724 tickets (FairAlbertaRoads, n.d.). Table 2 illustrates the increasing number of tickets issued between 2011 and 2014 and how the types of tickets issued for lower speed violations are on the rise.

Table 2.
Photo/Laser Rader Tickets Issued 2011–2014

Violation	2011	2012	2013	2014
1–5 km/h over posted speed limit	0	0	0	0
6–10 km/h over posted speed limit	2,462	3,252	12,403	66,847
11–15 km/h over posted speed limit	38,222	42,868	109,096	159,920
16–20 km/h over posted speed limit	76,689	85,027	203,721	159,920
More than 20 km/h over posted speed limit	29,981	31,849	97,500	68,749
Total	147,354	162,996	422,720	509,990

Note. From "City's aggressive photo radar enforcement is greasy," by D. Staples, 2015a. In public domain.

Between 2011 and 2014, violations for travelling 6 to 10 km/h over the posted speed limit went from 2,462 to 66,847 tickets, an increase of approximately 2,615%. As Zabjek (2015) highlighted in his article, soaring photo radar numbers are the new normal for Edmonton. One explanation for the rise of certain ticket thresholds is that guidelines for handing out a ticket can be arbitrarily and abruptly changed to create an increase in revenue. Rather than a ticket being issued for speeding 15km/hr over the posted limit, tickets are issued for violations under 10 km/hr and, in some cases, as low as 6 km/hr, leading to additional fine revenue for the municipality. By making small calibration changes in speed detection devices, a municipality can increase its enforcement revenue yield. When this occurs, violations appear to be tied to volume and not safety. When calibration changes are set to low levels, it creates an additional technical challenge for motorists to avoid tickets. Delaney et al. (2005) noted that when speed thresholds are reduced to certain levels, speedometers may not be sufficiently accurate to keep detected speed within enforcement tolerances (p. 416).

City of Edmonton Councillor Mike Nickel has suggested that the spike in tickets issued helps offset operational costs of running photo radar programs ("Petition calls," 2014), while other elected officials, including Michael Oshry, concede that "revenue is revenue for the city, whether it comes from property taxes or photo radar tickets" (Kent, 2014a, para. 15). A former City of Edmonton photo radar operator, Alan White, described the city's "hunger for revenue is just as strong as its intention to keep our roads safer" (Staples, 2015a, para. 1). White says if operators did not get a high number of violators, they were directed to other enforcement sites where more speeders would be ticketed. This blurs the line as to whether photo radar is a form of revenue generation or a traffic enforcement device.

Financial dependency on photo radar, whether perceived or real, creates budgetary challenges for municipalities. In Edmonton, there is a forecasted traffic ticket revenue deficit of approximately $2 million in 2016 even though there has been an increase in both the number of tickets issued and fines being assessed (Lazzarino, 2016). For municipalities dependent on ticket enforcement revenue, a deficit creates financial unpredictability and budgetary uncertainty.

A common refrain is photo radar is a revenue generating device that offers little safety benefit (Gandia, 2014; Staples, 2015b, 2016a). The City of Calgary reports that the municipality will require a significant tax increase to offset a loss of photo radar revenue (Gandia, 2014, para. 3). Elected official Diane Colley-Urqhart said, "There's the old issue whether or not [photo radar is] a cash cow, but basically how do we replace that $40 million in review that comes into police coffers every year?" (as cited in Gandia, 2014, para. 4). According to a 2006 Texas A&M University study, these types of statements about speed camera programs increase skepticism about the motive for their use (Willis, 2006, p. 7).

In May 2017, concerns regarding photo radar's use as a source of revenue generation caught the attention of the Alberta government. A joint review between the infrastructure and justice departments will examine policies in other jurisdictions and look at how photo radar sites in Alberta are selected (Graney, 2017, para. 4).

Those who object to speed cameras can be even more vocal when the technology is perceived to be covertly placed or located on roadways that are accepted by motorists as safe to speed. Delaney et al. (2005) noted that speeding is not always perceived as a safety problem, and some motorists believe that moderate speeding is not necessarily associated with increased crash risk if they otherwise drive safely (p. 406). In other circumstances, speed limits are perceived to be set too low at certain locations. Romer et al. (2009) cited other photo radar concerns, including speed detection cameras being used on downward slopes or with little or no warning of their presence (p. 11), being set up in areas with low traffic volumes or with no history of speed-related collisions, and being set up in areas where the speed limit changes suddenly. These types of photo radar enforcement approaches may result in a public outcry to remove the devices from the community.

Photo radar programs can be quickly discontinued, as was the case in Strathcona County, if concerns exist about the revenue motives of automated enforcement technology. When British Columbia enacted its photo radar program in the 1990s, it was introduced as a measure to curb speeding (Insights West, 2013). Initially, the program had reasonable public support, with two-thirds of British Columbians saying they supported photo radar (Chen & Warburton, 2006, p. 666). However, the site selection criteria were never made part of the legislation governing photo radar. The guidelines were weakened and then violated with increasing frequency as the program continued, allowing opponents to claim the program was motivated more by finance than safety. The program ceased operation on June 27, 2001 (Chen & Warburton, 2006, p. 666).

In Alberta, photo radar remains a popular enforcement tool. While safety concerns are most often cited to justify its use, the reality is that most programs produce at least a modest revenue gain. In the town of Morinville, one of the latest Alberta municipalities to hold a plebiscite on photo radar, the program generated approximately $300,000 per year for general revenue (Ramsay, 2014). Although the plebiscite to remove photo radar was narrowly defeated, Morinville Mayor Lisa Holmes said her council is committed to changing the automated enforcement program and acknowledged that the “photo radar program is not going to look the same” (as cited in Ramsay, 2014, para. 11).

Even law enforcement is expressing its doubts about the effectiveness of photo radar. Mike Steneker, a former RCMP officer with 32 years of service, reported that “photo radar does not make the roads safer and that speed is just easy to enforce compared to the real culprits” (as cited in Staples, 2016b, para. 4). Steneker reviewed collision reports over a 10-year period in the Leduc area, a city located south of Edmonton, Alberta. According to Steneker’s findings, “Not one traffic injury could be blamed on speed” (as cited in Staples, 2016b, para. 5). Instead, injuries and fatalities were caused by driving while distracted or impaired, merging too slowly, improperly maintaining cars and trucks, failing to wear seatbelts, and parking on the side of the road. Steneker believes that the public has been “brainwashed that speed is everything” when it comes to traffic safety (as cited in Staples, 2016b, para. 6).

Many municipalities struggle with the debate over whether photo radar exists to increase safety or generate revenue. In practice, there is no way to exclude or ignore the role of penalties and fines when evaluating mobile photo radar, or any automated traffic enforcement tool. Tickets serve as a critical component to improve traffic safety, even if they generate significant revenue for the municipality. As Tay (2010) concluded, “The need to issue tickets to maximize safety benefits does not completely nullify the possibility that cameras may still be operated partly to raise revenues” (p. 7).

3.8 Leading Practices on Automated Enforcement From Other Jurisdictions

Whether a jurisdiction is operating or considering implementing a mobile photo radar program, the following leading practices have been assembled from various municipalities, provinces, and states to help elected officials, administrators, and law enforcement officials avoid the pitfalls and criticisms of automated speed enforcement cameras.

According to the *Evaluation of the Photo Enforcement Safety Program of the City of Winnipeg*, municipalities should consider limiting photo radar to specific locations (Traffic Research Foundation, 2011, p. x). Targeting collision-prone locations with the most significant statistical risk of fatalities, injuries, and property-damage-only collisions will help to alleviate public and political accusations that photo radar is being used as a tool to generate revenue as opposed to improve traffic safety.

Beyond selecting specific sites for enforcement, ongoing studies are required to evaluate the overall effectiveness of mobile photo radar (Traffic Research Foundation, 2011, p. xi). Efforts should be made to improve data collection activities, to use data to support the existence of automated camera enforcement programs, and to demonstrate how mobile photo radar is reducing the frequency and severity of fatalities, injuries, and property-damage-only collisions. In their study on British Columbia's speed camera program, Chen and Warburton (2006) stressed that "the success of speed enforcement in reducing crashes should be rigorously evaluated and the results made public" (p. 675). The absence of evidence to justify the existence of mobile photo radar undermines the public support required to operate the program. Without public and political support, mobile photo radar, as were the cases in Strathcona County and British Columbia, can be quickly dismantled and discontinued.

One way to avoid the dismantling and discontinuing mobile photo radar is to demonstrate how the technology benefits other policing activities. One of the most overlooked aspects of mobile photo radar is that it relieves the burden on limited police resources to enforce traffic safety. Romer et al.'s (2009) *Evaluation of Montgomery County's Safe Speed Program* highlighted the importance of demonstrating how the use of mobile photo radar allows law enforcement officials to devote time to other policing priorities and demands (p. 81). In other words, what is the opportunity cost of discontinuing speed camera enforcement? Perhaps it means more time will be spent on traffic enforcement and less on investigating violent criminal code violations, property crime, and federal statutes. Chen and Warburton (2006) noted that since traffic fines represent a cost to motorists, a speed enforcement program is vulnerable to public perception; the public feels that it imposes a harm consisting of fines without creating offsetting benefits (p. 675). If mobile photo radar provides policing benefits, those advantages should be actively and frequently communicated to elected officials and the public.

3.9 Conceptual Framework

To understand mobile photo radar, it is useful to have a graphic representation of its operation. A logic model is one way to conceptualize the research question by creating a graph to express the basic idea of what is supposed to happen in a mobile photo radar program. Trochim (2001) said a logic model can "guide researchers in the process of identifying indicators and measures of the components of the graphic model" (p. 29). In Figure 3, a mobile photo radar logic model highlights what mobile photo radar is intended to accomplish and the impact it could have on the municipality. It summarizes key program elements and provides a summary of intended outcomes.

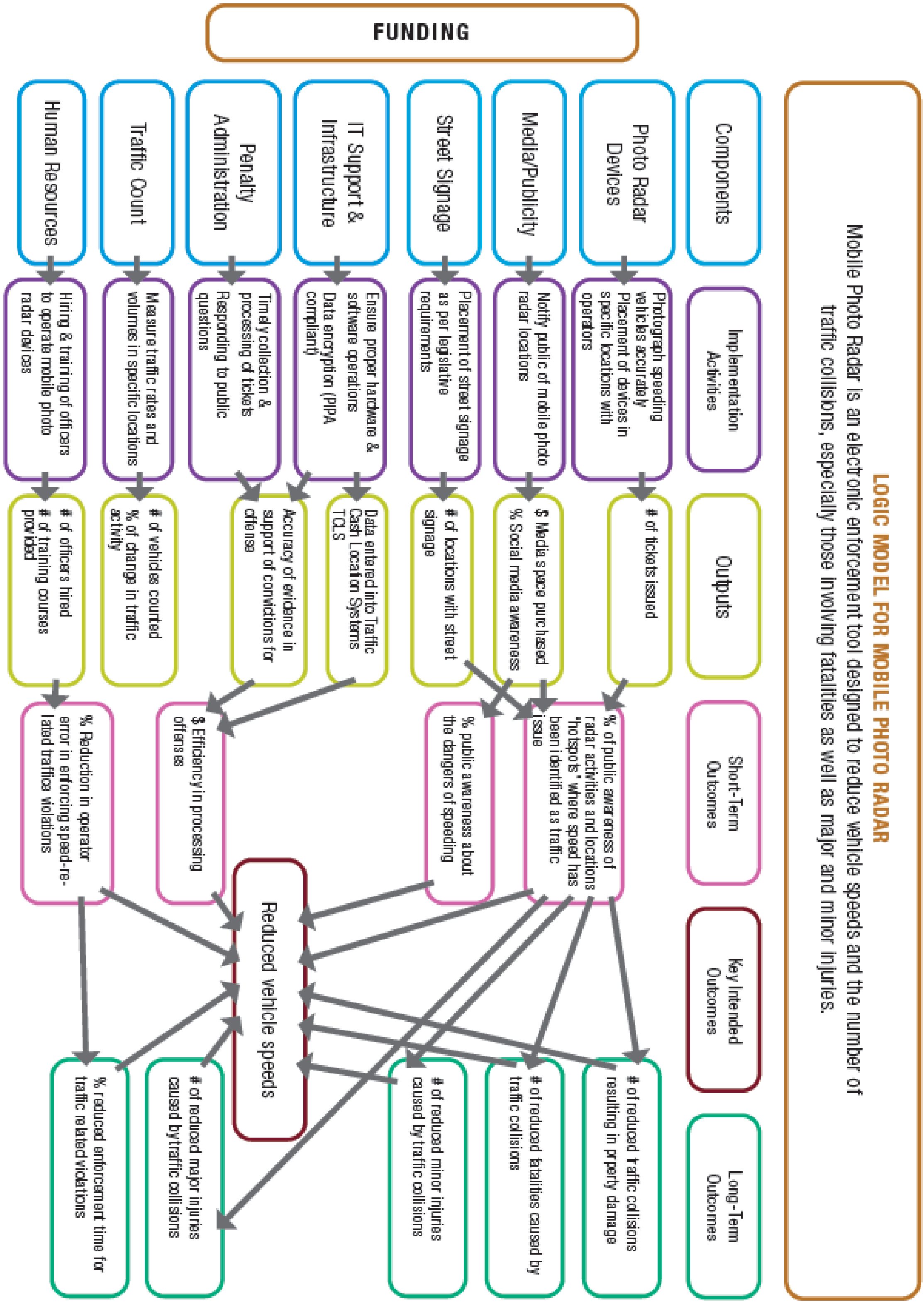

Figure 3. Mobile photo radar logic model.

To assist with the understanding of the research problem posed in this project, a conceptual framework is provided to offer a visual perspective between the major and dependent variables. It also highlights key program elements, intended outcomes, and key constructs examined in the project. Figure 4 presents the variables and hypothesizes relationships in this project.

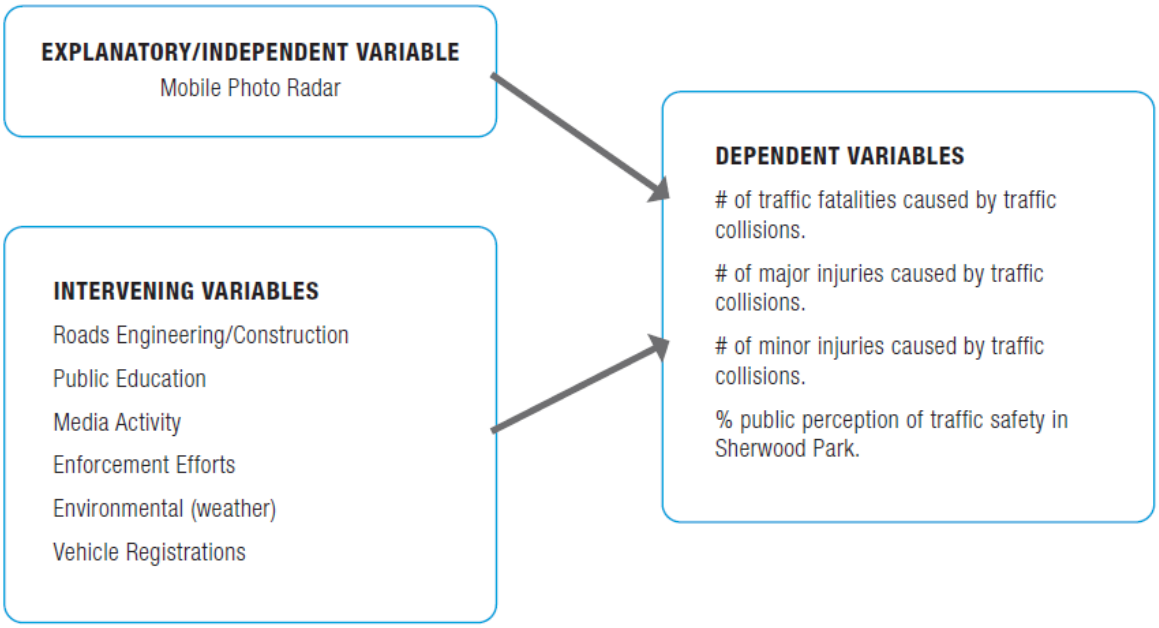

Figure 4. Conceptual framework of mobile photo radar.

Based on the literature review findings, a number of constructs were identified and defined, including fatality, major injury and minor injury, and property-damage-only. On the surface, a fatality appears to be a straightforward construct as the individual is either alive or deceased following a traffic collision. However, as is discussed in more detail in Chapter 4, Alberta Transportation's (2015) definitions for fatalities, major injury, and minor injury are more complicated than is expected.

As a construct, mobile photo radar units are mounted in vehicles operated by peace officers on or near a public roadway while other units are operated in a stand-alone device box near public roadways. The mobile photo radar system utilizes a radar control unit that detects vehicles speeds and then triggers activation of a camera when a vehicle exceeds the posted speed limit. Once the photo is captured, a violation ticket is sent to the registered owner of the vehicle, who may not be the actual driver committing the speeding offense.

3.10 Summary

When it comes to mobile photo radar, the literature and research regarding its traffic safety efficacy appears inconclusive. The quality of research in this area, as indicated by Pilkington and Kinra (2005) is "relatively poor" (p. 2).

Several researchers (Pérez, Marí-Dell'Olmo, Tobias, & Borrell, 2007, p. 1634; Pilkington & Kinra, 2005, p. 1; Wilson et al., 2006, p. 2) have found that photo radar research lacked methodological rigor. Wilson et al. (2006) revealed that all the studies they evaluated were observational and none used randomized controlled trials (p. 22). Considered the highest form of research evidence, randomized controlled trials are the best method to test the efficacy of interventions (Pilkington & Kinra, 2005, p. 5) and were absent from all the studies reviewed in this project.

While the literature review provided no shortage of photo radar studies, clear evidence on the effectiveness of photo radar remains elusive. Pérez et al. (2007) indicated that "most studies have not included satisfactory comparison groups or suitably controlled for potential confounders" (p. 1632). Another concern is that any rise or fall in traffic collisions could be due to chance or random fluctuations, which would be indicative of normal variation or regression to the mean. Another shortfall of existing research involves the standardized collecting and reporting practices of speed and collision data. Even the constructs for fatalities and major and minor injuries are more complicated than expected. When data are defined, collected, and coded in different ways, the task of drawing lessons from research is complicated. A more uniform approach in creating and reporting on constructs would allow researchers to compare the results of various studies more readily.

Due to data limitations provided by TCLS, this project also possessed many of the methodological shortfalls cited in the literature, including an absence of randomized control trials and controls for intervening variables. What this project sought to provide is a statistical comparison of fatalities, injuries, and property-damage-only collisions when mobile photo radar is removed from a community. It may be the first study of its kind to conduct this type of analysis and to attempt to answer the question: Do collisions "rebound" (Chen & Warburton, 2006, p. 675) and the severity of collisions increase following the discontinuation of a mobile photo radar program? The research provided by Strathcona County's TCLS revealed statistical data to challenge the efficacy of mobile photo radar in Sherwood Park, Alberta.

4.0 Methodology and Methods

4.1 Introduction

The research question for this study was, “Does the presence of mobile photo radar have a significant impact on the number of vehicle collisions in Sherwood Park, Alberta?” This section provides details on how data was gathered and interpreted in order to construct findings.

First, this section discusses methodology and why an interrupted time series research design was used to compare traffic collisions, injuries, and fatalities in Sherwood Park over a 16-year time frame. It is followed by a section on collection methods, including quantitative data supplied by Strathcona County’s TCLS as well as information provided through a Freedom of Information and Protection (FOIP) request on the revenue generated and number of violation tickets issued by mobile photo radar. The section concludes with an overview of the project’s limitations and delimitations, highlighting the project’s scope and challenges of studying the efficacy of mobile photo radar in Sherwood Park, Alberta.

4.2 Methodology

Evaluating the effects of a law, policy, or traffic safety campaign on an entire population is a form of nonexperimental research (Bellamy, O’Conner, & Spring, 2015). This project involved a population being measured several times before and after the intervention of mobile photo radar. It used an interrupted time series research design whereby any collision involving a fatality, major or minor injury, or property damage from one period of time was measured and compared to another period of time.

Interrupted time series is a one-group pretest and posttest research design. The data collected consists of a time series in the form of baseline measurements, followed by a change in the independent variable, otherwise called an intervention. According to Simon (1969), a time series method has two major advantages. First, historical data provides a set of observations of the phenomenon in question, which in this case is the number of collisions involving a fatality, major or minor injury, or property damage when mobile photo radar was the treatment condition. The second advantage of time series design is discovering how the events were ordered in time. In other words, if variables are measured at different points in time, then the earlier measured variables may exert a casual influence on the later, but the later variables cannot exert an influence on the earlier (Simon, 1969, p. 154).

A risk with interrupted time series is making a simple before-and-after comparison of the intervention and not taking other trends into account. This approach may result in overestimations or underestimations of the intervention effect (Eccles, Grimshaw, Campbell, & Ramsay, 2003, p. 47). Further, data may have issues related to seasonality and this factor must be considered as part of the analysis. It is important to note that in this project the total number of accidents per month was adjusted by scaling for population to a constant 2001 level. This was done in order to remove the effects of population growth on the time series.

Interrupted time series design uses several rounds of observations before-and-after the introduction of the independent treatment variable of mobile photo radar. This approach is optimal when the independent variable is expected to have an immediate, measurable effect, and if the treatment is introduced, or in this case, removed, all at once in all situations. It is diagramed as shown in Figure 5.

O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	X	O13	O14	O15	O16

Figure 5. Diagram of interrupted time series design.

4.3 Methods

Project preparation began with collecting and reviewing qualitative background information about Strathcona County's mobile photo radar program. Historical information about the program was identified and secondary sources of information about the program's development, implementation, and delivery were obtained.

Monthly quantitative data gathered from Strathcona County's TCLS (R. Anders, personal communication, April 10, 2017) were analyzed for 12 years while mobile photo radar was operational (January 1, 2001, to September 30, 2012) and for 4 years after its removal (October 1, 2012, to September 30, 2016). The project excluded from analysis collisions occurring in rural areas and on provincial highways. By law, photo radar is not legislated on provincial roadways. Through a FOIP request, Strathcona County provided data related to enforcement, including the number of photo radar tickets issued and revenue collected between 2001 and 2012 (G. Einarson, personal communication, April 21, 2017).

All statistical analysis computing used R, which provides a wide variety of statistical and time series analysis tests. R provides an open source and free software program for data analysis as well as graphs. The language and environment for R was downloaded from http://www.r-project.org/.

4.4 Development of Mobile Photo Radar Survey

In 2015, Strathcona County conducted a resident survey on traffic safety. The goal was to establish resident perceptions and attitudes towards traffic safety and traffic safety initiatives (Strathcona County, 2015, p. 1). The survey was administered by telephone randomly to 500 adults living in Strathcona County (Strathcona County, 2015, p. 1). Although the survey asked broad questions regarding traffic safety using a combination of multiple choice and open-ended questions, no specific questions directed were towards mobile photo radar as a possible enforcement tool.

As the Traffic Research Foundation (2011) observed, when evaluating photo enforcement programs, "It is essential to understand public attitudes towards these programs" (p. 2). The reason for this is that the act of driving is more than just the mechanical operation of a vehicle. Driving is a complex process comprising individual actions that are impacted by social, environmental, and contextual elements found both inside and outside of the vehicle (Auguste, 2015). The purpose of providing a survey in this project was not to replace or replicate the biannual survey conducted by Strathcona County; instead, it was intended as a supplemental tool to provide additional feedback and contextual information on driver behaviour and attitudes towards traffic safety, speed, and mobile photo radar usage in Strathcona County. The survey is designed to provide feedback and contextual information on applied driver behaviour and attitudes towards traffic safety, speed, and mobile photo radar usage in Sherwood Park, Alberta. Due to the cost of conducting the survey and the project's scope, the research instrument is included in the project but has not been deployed to collect and analyze responses.

The survey (see Appendix 1) consists of 15 questions within four separate sections. The first section uses dichotomous and multiple choice questions to obtain demographic information and to ensure participants live in Sherwood Park, are 18 years of age or older, and define their age range. The next section includes dichotomous and multiple choice questions to capture broad perceptions of traffic safety. This is followed with a multiple-choice section on broad perceptions of speed. The final section of the survey asks a range of dichotomous and multiple choice questions regarding mobile photo radar.

According to the 2015 census, Strathcona County has a population of 68,782 (Strathcona County, 2016). The survey was constructed to target a random, representative sample of 500 residents living in Strathcona County, with 70% being drawn from the urban area and 30% from the rural parts of the municipality, reflective of the proportionate distribution. The survey would be open to Strathcona County residents who are 18 years of age or older and would include a balance of respondents with landlines and cellular telephone numbers. Finally, through the survey sample, the objective should be to mimic age and gender quotas from Statistics Canada to ensure that the survey respondents are representative of Alberta's demographics. Using a 95% confidence internal, the same standard maintained by Strathcona County, a survey frame consisting of 500 individuals should provide overall results accurate to ± 4.37% 19 times out of 20.

A telephone survey research design was used to develop the survey. Questions, in part, were based on other public opinion tools developed for municipalities, including Strathcona County's *2015 Traffic Safety Survey* and the Traffic Research Foundation's (2011) *Evaluation of the Photo Enforcement Safety Program of the City of Winnipeg*. Trend Research, an Edmonton-based research company, reviewed the survey instrument, conducted a pretest involving 10 interviews to ensure questions were understood by respondents, and provided feedback. It is estimated that the survey would take approximately 10 minutes to complete.

4.5 Project Limitations and Delimitations

Limitations and delimitations are inherent in research, and an investigation into traffic safety is no different. Limitations are the perceived weaknesses in a research project that are mostly beyond the control of the researcher due to areas such as funding, research design, statistical model constraints, and other factors. Limitations need to be identified in the project in order to better understand how certain research restrictions potentially affected the project design and results. Alternatively, delimitations are the boundaries set by the researcher to help ensure the research scope does not become impossibly large to complete.

4.5.1 Delimitations

Mobile photo radar is one of many automated traffic enforcement tools. In fact, Sherwood Park continues to operate automated red light and intersection speed detection cameras even though mobile photo radar has ceased to exist in the community. This project focused exclusively on mobile photo radar; the project was not designed as a comprehensive evaluation of the traffic enforcement program provided in Strathcona County.

An economics analysis on mobile photo radar was not included. Unlike Chen and Warburton (2006), the net societal benefits of operating a mobile photo radar program were not analyzed, and a net savings or cost of operating mobile automated enforcement was not determined. Information related to the costs of running the program, which includes start-up, operational, police, and court expenses, was not included.

A process evaluation of mobile photo radar and a review the program's implementation, delivery, and operation were not included. Although elected officials, administrative staff, and law enforcement officials were contacted by email for background materials and data, individual interviews were not conducted to identify what processes worked well and what challenges or gaps, if any, existed during the operation of the mobile photo radar program.

Experiments with photo radar at various intersections or streets were not conducted. It was not possible to conduct a before-and-after experimental design with control groups to evaluate the effectiveness of mobile photo radar in various locations. In addition, no data comparisons were made involving fatalities, major injuries, and minor injuries with other municipal jurisdictions that operated mobile photo radar.

4.5.2 Limitations

Limitations are the restrictions on research that have the potential to affect the project design and results. When considering limitations, one area worth exploring is the reliability or the quality of measurements. Data reliability poses several concerns when it comes to traffic safety in general and mobile photo radar specifically. Several extraneous variables may affect speeding, otherwise known as the dependent variable, and these variables limit the project's ability to establish a direct cause-and-effect relationship with the treatment condition of mobile photo radar.

One of the key limitations was the data quality related to the hours of operation of mobile photo radar in Sherwood Park (G. Einarson, personal communication, April 21, 2017). Several months indicated impossibly high numbers of enforcement hours, including 10,359 hours in March 2009 or the equivalent of 334 hours per day. This prevented the study from analyzing whether hours of mobile radar enforcement were correlated to collision rates.

Table 3 examines four additional extraneous variables and how they may have impacted findings in this project. No controls were in place for any of the variables during the study, which may have exerted a significant influence on the results. While it is impossible to avoid every extraneous variable in this type of study, most of the variables listed are situational. They are characteristics of the environment in which the nonexperimental research is taking place. By identifying these variables, future studies may be able to control for them and provide a more accurate cause-and-effect relationship with the dependent variable.

Table 3.
Extraneous Variables and Mobile Photo Radar

Extraneous variable	Potential influence
Road engineering/construction activity	Construction activity has the potential to influence traffic speeds and patterns. Also, roads may be narrowed or widened to influence traffic speeds. Engineered traffic calming efforts, such as speed bumps, may influence the dependent variable.
Public education	Public education efforts, including the posting of photo radar locations and media relation events to highlight enforcement activities, may influence the dependent variable.
Enforcement efforts (reporting and activities)	Traffic enforcement activity fluctuates with policing priorities. Reporting of injuries may not be consistent throughout the police department.
Environmental (weather)	Weather patterns fluctuate. The amount of snow, rain, wind, and other conditions impact the dependent variable and may cause collisions that are not entirely attributable to speed.
Registered drivers/traffic counts	The total number of registered drivers during the observation period may cause an increase or decrease in the number of collisions.
	Vehicle traffic counts at specific locations where photo radar is operational may reveal why certain locations have more or fewer collisions.

This project used an interrupted time series design, which Simon (1969) indicated is “vulnerable to changes in general conditions that may be relevant to the phenomenon being studied” (p. 154). The risk when performing time series design is that conclusions can be too easily drawn from a before-and-after comparison of the intervention effect. As it is well known, correlation is not necessarily causation. For example, solely comparing an intervention without taking into account temporal or seasonal trends, such as weather, may lead to an overestimation or underestimation of the intervention effect.

Validity presents another limitation concern. According to Trochim (2001), validity is defined as the "best available approximation to the truth of a given proposition, inference, or conclusion" (p. 20). One way to examine validity in mobile photo radar is to examine the project's constructs, which provide a common language and shared meaning that assists researchers in communicating content with clarity and precision.

In this project, a fatality appears to be a straightforward construct—the individual is either alive or deceased following a traffic collision. But Alberta Transportation (2015) has a more detailed definition of what constitutes a fatality as "the death of a person that occurs as a result of motor vehicle collision within 30 days of the collision" (p. xi). The definition of what includes a major or minor injury requires even more qualifiers. Alberta Transportation has defined a major injury as "persons with injuries or complaints of pain who went to the hospital and were subsequently admitted, even if for observation only" (2015, p. xi). A minor injury is defined as "persons with injuries or complaints of pain that went to the hospital, were treated in emergency (or refused treatment) and sent home without ever being admitted to the hospital" (Alberta Transportation, 2015, p. xi). The reality is that the construct used to understand a fatality, as well as a major and minor injury, may be defined differently in Alberta than in other countries, states, and provinces, making a straight comparison of research results difficult to achieve.

In addition, there were insufficient time and resources to confirm whether every entry into the Strathcona County's TCLS was inputted correctly (R. Anders, personal communication, April 10, 2017). Admittance to the hospital is the key differential between being classified as having had a major or minor injury. Did police services know whether people with injuries or complaints of pain went to hospital and were sent home without ever being treated? It was not possible to assess whether police or emergency services entered these data correctly.

The project relied on quantitative data that captured the total number of traffic collisions in Sherwood Park. This is different than capturing data on total number of targeted speed crashes. Results that depend on the total number of traffic collisions may be considered a form of sampling bias since collisions are caused by a number of factors, including impaired driving and adverse weather conditions, that may or may not have any relationship with speeding. The study's external validity is threatened by sampling bias—a choice between collecting total crashes instead of targeted crashes. Data were not collected on targeted crashes, including right-angle and rear-end collisions, which tend to involve speeding (Smith, 2004). Some researchers have argued that evaluations should not rely on data from crashes that cannot be prevented by photo radar. Shin, Washington, and Schalkwyk (2009) advised, "As a general result, the use of total crashes instead of targeted crashes will lead to inaccurate estimates of safety impacts" (p. 394). Although data related to total number of collisions involving a fatality, major injury, and minor injury were evaluated, data involving right-angle and rear-end collisions were not isolated and examined.

The final limitation is the period of time used to observe the data. In a time series design, it is crucial to have a significantly long period of baseline data to make observations. This project used a 16-year time horizon, of which 12 years represented the baseline and 4 years were used to examine the intervention, which in this case was the discontinuation of mobile photo radar. Simon (1969) summarized that

> in order to be confident about the results of time series research, one must try to get enough observations, over a long enough period of time, to be fairly sure that long term trends and whatever cyclical effects there might be will both show up in the data. (p. 156)

Although more baseline data would have increased the project's validity, a 16-year time horizon with 17,250 unique observations was more than sufficient to produce results suitable for an evaluation of mobile photo radar's effect on traffic safety.

4.6 Summary

Using an interrupted time series research design approach, this project measured major or minor injury, as well as property-damage-only collisions, and compared the results to another period of time. The population of Sherwood Park served as its own control over a 16-year period. From January 1, 2001, to September 30, 2012, the treatment condition of mobile photo radar was used on the control population and then from October 1, 2012, to September 30, 2016, the treatment condition was removed and a comparison of the dependent variables was examined.

Several extraneous variables were identified, including road engineering and construction activity, public education, enforcement efforts, environmental factors, and registered drivers. The data available included in this project did not control for these intervening variables. Despite the limitations and delimitations, the baseline research provided a 16-year time frame with over 17,000 unique observations, providing the project with more than sufficient data to conduct an evaluation of mobile photo radar's effect on traffic safety in Sherwood Park, Alberta.

5.0 Findings

5.1 Introduction

This section reports on the project's findings. The findings are based on an interrupted time series research design approach involving 17,260 observations over a 16-year period. Quantitative data were gathered from Strathcona County's TCLS as well as information provided through a FOIP request on the number of violation tickets issued and revenue generated when mobile photo radar was operational. Once analyzed, the data provided insights into whether the existence of mobile photo radar program in Sherwood Park, Alberta, is independent of fatalities, injuries, and property-damage-only collisions.

5.2 Data Analysis

Strathcona County's TCLS (R. Anders, personal communication, April 10, 2017) supplied the quantitative monthly collision data for 12 years before and 4 years after the removal of mobile photo radar. The project excluded analysis of any collisions occurring in rural areas and on provincial highways. By law, photo radar is not legislated on provincial roadways.

With information supplied by Strathcona County as well as census figures, several statistical tests were conducted on the TCLC data set.

The total number of collisions per month was adjusted for population growth. This was achieved by scaling for population and adjusting the number of car collisions per month to a constant 2001 population. Scaling for population allows the project to remove the effects of population growth on the time series.

The time series in question was then analyzed graphically. Then a formal test was conducted to determine the presence of stationarity in the series. A stationary series is one which has a constant mean, variance, and autocorrelation. A nonstationary series with an inconstant mean, variance, and autocorrelation will show unpredictable patterns, and thus cannot be used to conduct reliable forecasting.

An Ordinary Least Squares regression was run in order to determine the linear nature of the relationship between the presence and absence of photo radar, and the number of traffic collisions per month taking into account the other independent variables mentioned above. The dependent variable of total number of traffic accidents per month, as explained, is scaled for population in order to eliminate the effects of population on the series.

To determine the presence or absence of a structural break in the time series from September 2012 onwards (the point at which photo radar is removed), a Chow test was conducted.

Finally, a Poisson distribution was generated in order to determine the probability distribution of a specific number of collisions occurring in a certain month. Again, two separate distributions were generated for comparison purposes, one using data when photo radar was present and the other using data for when photo radar was absent.

5.2.1. Population Adjustment

Given that population growth in urban Sherwood Park has been rising while mobile photo radar was operational (see Table 4), the total number of collisions was scaled back to a constant population in 2001 of 47,645. Appendix 2 provides the full data set, including how the new variable of adjusted population took into account the population differences.

Table 4.
Population Growth in Sherwood Park

Year	Census type	Urban Sherwood Park
2001	Federal	47,645
2003	Municipal	51,544
2005	Municipal	55,063
2006	Federal	56,845
2008	Municipal	59,409
2009	Municipal	61,660
2011	Federal	64,733
2012	Municipal	65,465
2015	Municipal	68,782
2016	Federal	70,618

Note. From Strathcona County Census 2015 (Strathcona County, 2016).

5.2.2 Total Collisions in Categories

When plotting population-adjusted collisions on a monthly, quarterly, or annual basis (see Figures 6, 7, and 8, respectively), it is observed that the overall trend for total number of collisions per year increases. However, on a monthly and quarterly basis, the peaks in the number of collisions dip after the 2012 period when mobile photo radar is removed. It is unclear as to whether this is directly due to the removal of mobile photo radar, an increase in traditional traffic enforcement, or another intervening variable. As a result, further investigation is needed through the use of an Ordinary Least Squares regression.

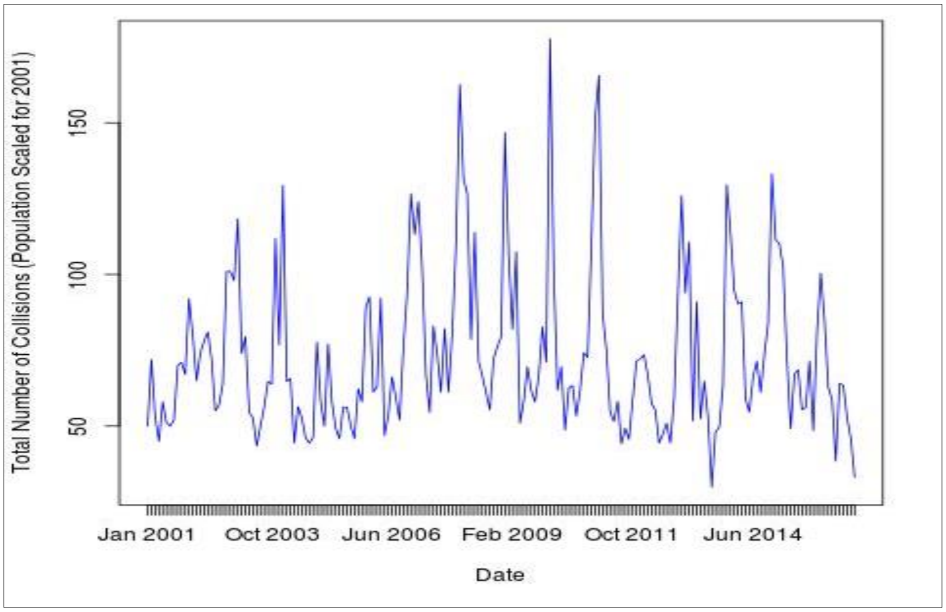

Figure 6. Total number of collisions per month (population adjusted).

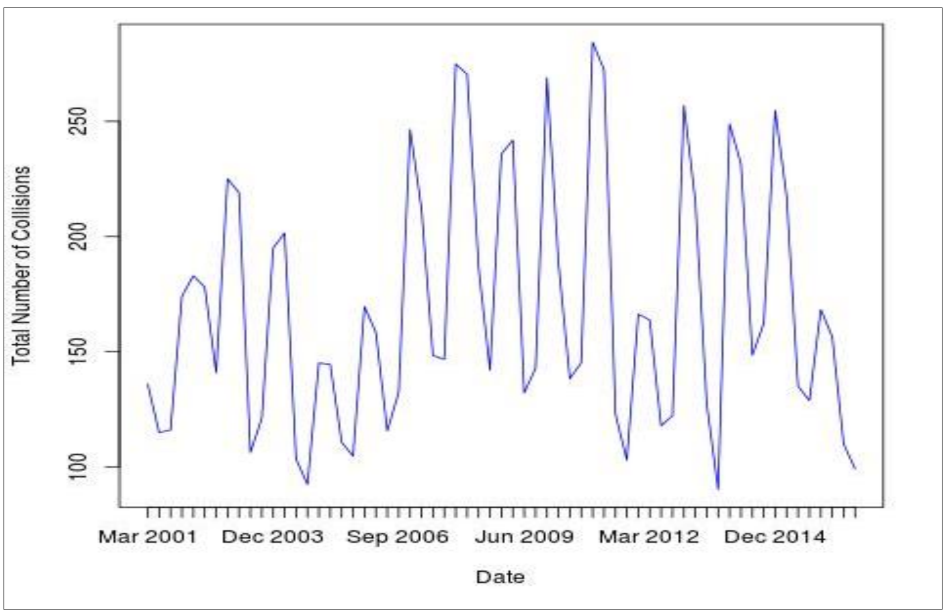

Figure 7. Total number of collisions per quarter (population adjusted).

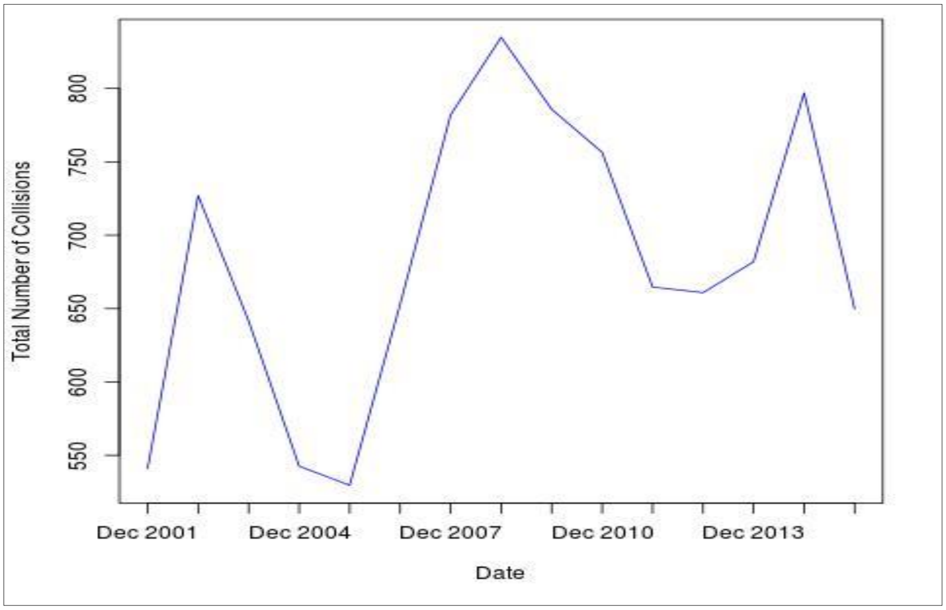

Figure 8. Total number of collisions per year (population adjusted).

5.2.3 Stationarity Testing

A time series with seasonality present will not demonstrate stationarity. Nonstationary time series data may produce unreliable and spurious results. As a result, any potential forecasts or investigation of correlation between variables will likely be biased since the values of certain variables will be influenced by seasonality in different periods. The solution to this problem is to transform the time series data so that it becomes stationary, one where statistical properties such as mean, variance, and autocorrelation are all constant over time.

When the time series for the total number of collisions per month (scaled for population) is plotted from January 2001 to September 2016, it is observed that the series visually resembles that of a stationary process—one with a constant mean, variance, and autocorrelation (see Figure 9). If this were not the case, the project would expect to see a particular trend or cycle that shows a varying mean and variance over time. This does not appear to be the case here, and it is hypothesized that the time series is not integrated of any order and therefore does not possess a unit root.

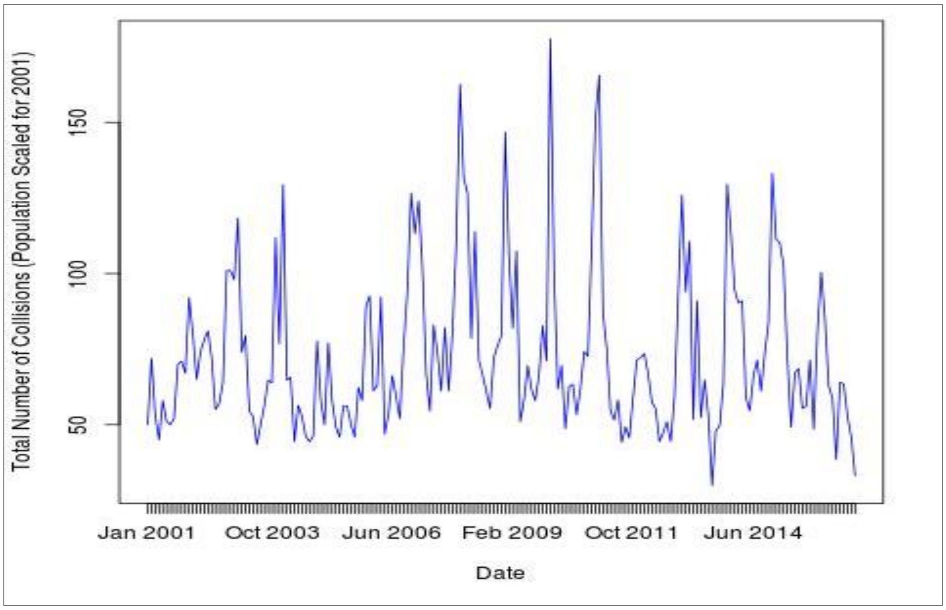

Figure 9. Total number of collisions per month (population scaled for 2001).

In order to conduct tests such as Ordinary Least Squares to establish the correlation between photo radar and total number of collisions, data must be stationary since a nonstationary series with a fluctuating mean and variance inherently does not have predictive properties. In order to confirm if the time series is trend stationary, the Kwiatkowski–Phillips–Schmidt–Shin or KPSS is used to determine if a time series is stationary around the mean or linear trend, or is stationary due to a unit root. KPSS test for trend stationarity is conducted, where:

the null hypothesis = the time series is trend stationary

the alternative hypothesis = the unit root is present

When a KPSS test for trend stationarity is conducted, we see that the null hypothesis of trend stationarity cannot be rejected at the 5% level given a p-value of 0.1 (see Table 5). Therefore, the time series in question is stationary and does not need to be first-differenced.

Table 5.

KPSS Test for Trend Stationarity for Population

Variable	KPSS trend	Truncation lag parameter	p-value
Total population adjusted (total_populationadjusted)	0.11864	3	0.1

However, when the graphs for the independent variables in the study are observed (see Figures 10 and 11), it is evident that the variables do not show a constant mean, variance, or autocorrelation over time. Rather, the fluctuations appear to be cyclical and significantly deviate across time periods.

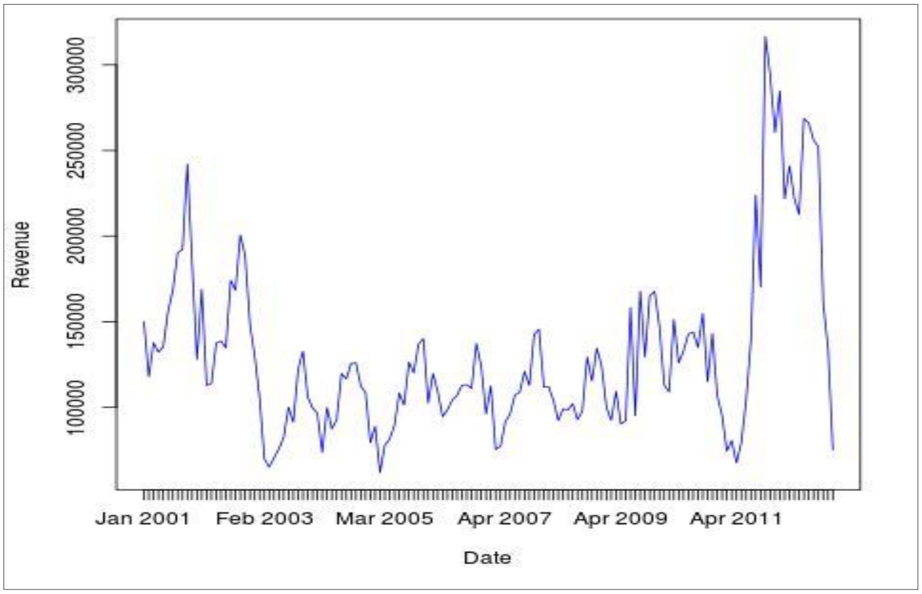

Figure 10. Revenue per month.

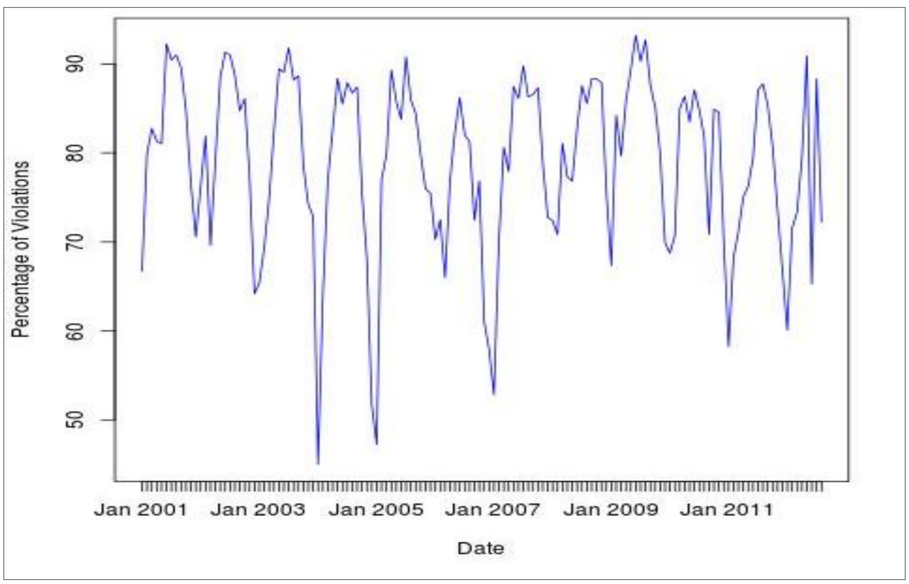

Figure 11. Percentage of violations per month.

Moreover, when the KPSS test for trend stationarity is run on the variables of photo radar revenue and percentage of violations per day, we see that at a p-value of 0.01, we reject the null hypothesis of trend stationarity at the 5% level of significance (see Table 6).

Table 6.
KPSS Test for Trend Stationarity for Revenue and Violations Per Day

Variable	KPSS trend	Truncation lag parameter	p-value
Revenue (revenue)	0.39113	3	0.01
Percentage of violations per day (percentageofviolations)	0.79295	3	0.01

However, when the above three independent variables (population, revenue, and percentage of violations per day) are first-differenced and the KPSS tests run again, it is observed that the resulting p-values of 0.1 are insignificant at the 5% level of significance (see Table 7), and therefore the null hypothesis of trend stationarity cannot be rejected.

Table 7.
KPSS Test for First-Differenced Series

Variable	KPSS trend	Truncation lag parameter	p-value
Photo radar revenue (diffvariablerevenue)	0.02908	3	0.1
Percentage of violations per day (diffpercentageofviolations)	0.026701	3	0.1

Given that the above independent variables become stationary once first-differenced, the first differences of these variables are accordingly used in the subsequent Ordinary Least Squares regression.

5.2.4 Ordinary Least Squares Regression

In the previous section, it was observed that when looking at the total number of collisions adjusted for population, there is no particular trend or indication of stationarity in the series. However, this was deemed to be present for the independent variables. In this regard, it is deemed appropriate to run an Ordinary Least Squares regression to determine the relationship between mobile photo radar presence and number of collisions, and indeed to determine if extraneous variables such as weather have a greater impact on the number of collisions per month.

For the revenue per month variable, it was hypothesized that a time lag could potentially exist between revenue spent on photo radar per month and the number of traffic collisions. To test this, a cross-correlation function (ccf) was run on the total number of population-adjusted collisions and the first-differenced variable of photo radar revenue. Appendix 3 provides for the cross-correlation table. The variable for total number of collisions is not first-differenced, as this series is already deemed to be stationary. Instead, the first-differences of photo radar revenue is regressed on the population and adjusted for the total number of collisions (2:189). This test is done to examine if the lag between the two variables is strongest at different time periods or the same. It was found that the correlation is highest at lag 0, and thus the Ordinary Least Squares regression was accordingly treated as having no time lag between the two variables (see Figure 12).

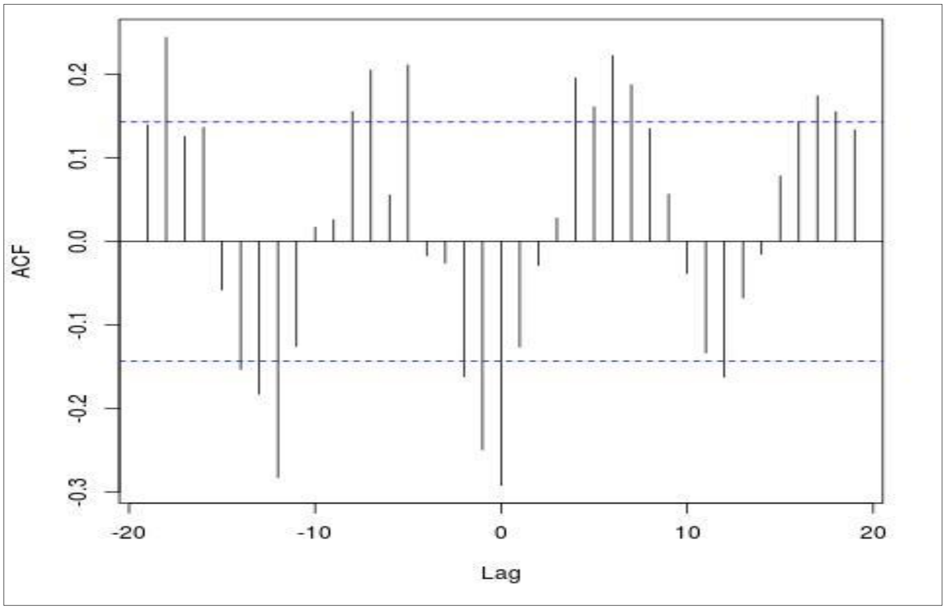

*Figure 12.*Total Population Adjusted

When the OLS regression is run, the following output is obtained:

```
Call:
lm(formula = total_populationadjusted[2:189] ~ diffvariablerevenue +
    diffpercentageofviolations + weatherlogit[2:189], data = mydata)

Residuals:
    Min      1Q  Median      3Q     Max
-57.304 -17.055  -6.098  13.553  89.548

Coefficients:
                              Estimate Std. Error t value Pr(>|t|)
(Intercept)                  7.008e+01  2.400e+00  29.198  < 2e-16 ***
diffvariablerevenue         -2.589e-04  6.939e-05  -3.732 0.000253 ***
diffpercentageofviolations -6.257e-01  2.051e-01  -3.051 0.002615 **
weatherlogit[2:189]          6.569e+00  3.701e+00   1.775 0.077545 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 24.99 on 184 degrees of freedom
Multiple R-squared:  0.1213,  Adjusted R-squared:  0.107
```

F-statistic: 8.467 on 3 and 184 DF, p-value: 2.674e-05

According to this regression output, several key results are identified:

- When photo radar revenue per month increases by $1, then the number of collisions per month falls by 0.0002589 units.
- When the percentage of violations as detected by photo radar increases by 1 unit, then the number of collisions per month falls by 0.6257 units.
- When incidences of photo radar violations pertaining to weather conditions are present in a particular month, the number of traffic collisions in that month increases by 6.569 units.

The revenue and percentage of violations variables are significant at the 1% level of significance with p-values below 0.01. The weather conditions (weatherlogit) variable is significant at the 10% level of significance with a p-value of 0.0698. Moreover, when a Variance Inflation Factor (VIF) test was run for the above regression, VIF values close to 1 were observed (see Table 8). This indicates that the regression model does not suffer from multicollinearity.

Table 8.
Variance Inflation Factor Test Results

Variable	VIF value
Revenue (diffvariablerevenue)	1.004166
Percentage of violations (diffpercentageofviolations)	1.000101
Weather (weatherlogit [2:189])	1.004069

Note. > vif(reg1)

However, the regression must also be tested for serial correlation using the Durbin-Watson test, and heteroscedasticity using the Breusch-Pagan test. The Durbin-Watson test for autocorrelation is used to test if past values of a variable have a significant influence on the present variable. In other words, the test helps to determine if autocorrelation is present or not. Presence of autocorrelation violates the assumptions of Ordinary Least Squares that observations of the error term are uncorrelated with each other. Therefore, this will likely lead to bias in the standard errors, which would lead to unreliable hypothesis testing, particularly by increasing the probability of a Type 1 error: rejecting a true null hypothesis.

Durbin-Watson statistic:

$$d = \frac{\sum(\hat{e}_t - \hat{e}_{t-1})^2}{\sum \hat{e}_t^2}$$

where $\hat{e}_t$ = error term

The respective hypotheses are as follows:

null hypothesis = no serial correlation

alternative hypothesis = serial correlation

The Breusch-Pagan test for heteroscedasticity is a way to examine errors of regression. It is run to test if the variance in the project's regression model is constant. Put simply, heteroscedasticity refers to a circumstance in which the variability of a variable is unequal across the range of values of a second variable that predicts it (Taylor, 2013). If variance is constant, this property is known as homoscedasticity. The null and alternative hypothesis for the Breusch-Pagan test is as follows:

null hypothesis = homoscedasticity
alternative hypothesis = heteroscedasticity

where for a regression model:

$$y=\beta_0+\beta_1 x+u$$

the squared residuals are regressed on the independent variables as follows:

$$\hat{u}^2=\gamma_0+\gamma_1 x+v$$

The Durbin-Watson test was found to be significant at the 5% level with a p-value of 0, indicating that serial correlation is present in the model (see Table 9).

Table 9.
Durbin-Watson Test Results

Durbin-Watson value	p-value
1.0146	4.839e-12

Note. > dwtest(reg1). Alternative hypothesis: true autocorrelation is greater than 0.

However, the differencing of the total number of collisions adjusted for population did, as demonstrated by KPSS test, make the variable stationary. Thus, it can be said that the data follow a stationary AR(1) process. In this regard, the serial correlation can be corrected using a Cochrane-Orcutt procedure, which is used to correct autocorrelation in time series data.

When the Cochrane-Orcutt procedure is applied, the following output is derived:

```
Call:
lm(formula = total_populationadjusted[2:189] ~ diffvariablerevenue +
   diffpercentageofviolations + weatherlogit[2:189], data = mydata)

                        Estimate  Std. Error t value  Pr(>|t|)
(Intercept)              6.9376e+01  2.4001e+00  29.198 < 2.2e-16 ***
diffvariablerevenue       -7.2897e-05  6.9394e-05  -3.732 0.0002534 ***
```

```
diffpercentageofviolations -4.4713e-01  2.0506e-01  -3.051 0.0026146 **
weatherlogit[2:189]        7.9532e+00  3.7007e+00   1.775 0.0775450 .
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 21.1094 on 183 degrees of freedom
Multiple R-squared:  0.0844 ,  Adjusted R-squared:  0.0694
F-statistic: 5.6 on 3 and 183 DF,  p-value: < 1.039e-03

Durbin-Watson statistic
(original):    1.02666 , p-value: 8.647e-12
(transformed): 2.05070 , p-value: 6.734e-01
```

With a p-value of 0.6734 for the Durbin-Watson statistic once the regression model is transformed using Cochrane-Orcutt, this is highly insignificant at the 5% level, indicating that serial correlation is no longer present in our model. Moreover, when the updated model is tested for heteroscedasticity using the Breusch-Pagan test, a p-value of 0.06773 is indicated to be insignificant at the 5% level (see Table 10), and therefore this indicates that the null hypothesis of homoscedasticity cannot be rejected.

Table 10.
Breusch-Pagan Test Results

Breusch-Pagan value	df	p-value
7.1345	3	0.06773

Note. > bptest(orcuttreg1).

According to the updated model:

- When photo radar revenue per month increases by $1, then the number of collisions per month falls by 0.000072897 units.
- When the percentage of violations as detected by photo radar increases by 1 unit, then the number of collisions per month falls by 0.44713 units.
- When incidences of photo radar violations pertaining to weather conditions are present in a particular month, the number of traffic collisions in that month increases by 7.9532 units.

We see that while the photo radar variable (as measured by revenue) is statistically significant, weather (presence of which is assumed by presence of recorded plate violations due to weather conditions) is also significant and the coefficient is much larger. This indicates that extraneous factors such as weather have a much greater impact on the number of traffic collisions. The analysis clearly shows that mobile photo radar alone has a negative effect on the frequency of collisions; however, the effect is diminutive.

5.2.5 Chow Test

Given that the Ordinary Least Squares regression output showed an insignificant relationship between the presence/absence of photo radar and the total number of collisions adjusted for population, the Chow test was performed to determine if a structural break exists at the point where photo radar was removed, i.e. September 2012. The Chow test reveals whether regression coefficients are different for split data sets. Basically, it tests whether one regression line or two separate regression lines best fit a split set of data:

> null hypothesis = no structural break in time series
> alternative hypothesis = structural break in time series

To do this, three regressions were run:

1. A pooled regression with total accident data from August 2008 to September 2016 inclusive.
2. A regression with total accident data from August 2008 to August 2012 inclusive (termed regression A).
3. A regression with total accident data from September 2012 to September 2016 inclusive (termed regression B).

A Chow Test was then run using the residual sum of squares (RSS) statistics for the three regressions. See Appendix 4 for regression results.

$$\frac{(RSS_P) - (RSS_A + RSS_B)/k}{(RSS_A + RSS_B)/(N_A + N_B - 2k)}$$

where RSS_P = pooled regression, RSS_A = regression A, RSS_B = regression B, N_A = degrees of freedom in A, N_B = degrees of freedom in B, and k = regressors in regression model (including intercept).

RSS_P = 113507

RSS_A = 71240.68

RSS_B = 55249.77

$N_A = 47$

$N_B = 47$

$k = 2$

$$\frac{(113507) - (71240.68 + 55249.77)/2}{(71240.68 + 55249.77)/(47 + 47 - 2(2))} = 2.496181$$

A Chow statistics of 2.496181 is yielded. With an F critical value of 1.623755 (given 47 degrees of freedom in both the numerator and denominator, and a critical value of .05), the null hypothesis of no structural break is rejected. Therefore, the Chow test indicates that a structural change in collisions is noticed after photo radar data has been removed. When analyzing the monthly graph, a change in trend can be observed in that the graph is showing lower peaks in collisions after September 2012 (see Figure 13).

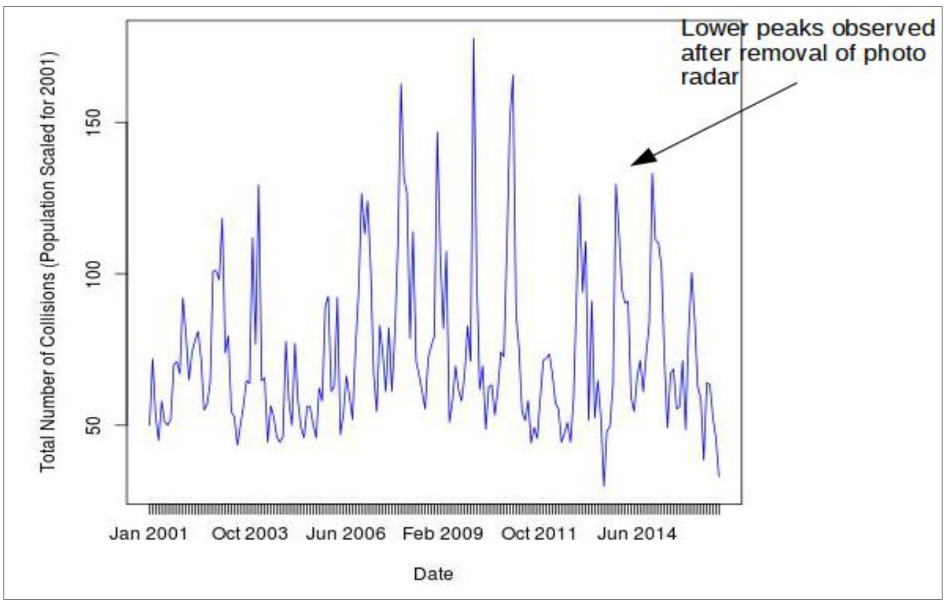

Figure 13. Total number of collisions per month (population scaled for 2001).

However, this trend cannot be concluded to be due to the removal of photo radar directly. It could be that an extraneous variable not yet accounted for in the study, such as weather or increased traditional traffic enforcement, is contributing to the structural break. Therefore, this finding warrants further investigation.

5.2.6 Poisson Distribution

A Poisson distribution involves calculating the probability of independent events occurring within a fixed time or space. Given the data set is based on total number of collisions per month, it is possible to use the Poisson distribution as a measurement of probability in percentage terms of a certain number of collisions occurring per month. Another way to consider a Poisson distribution is that it predicts the degree of spread around a known average rate of occurrences.

Typically, the Poisson distribution applies when four characteristics are met: 1) the event can be counted in whole numbers; 2) occurrences are independent, so that one occurrence neither diminishes nor increases the chance of another; 3) the average frequency of occurrence for the time period in question is known; and 4) it is possible to count how many events have occurred.

The Poisson distribution is a discrete probability distribution, which is used in this instance to determine the probability of observing k number of collisions within a certain interval—in this case, during a month.

$$\text{probability of observing } k \text{ number of collisions within an interval} = e^{-\lambda}\frac{\lambda^k}{k!}$$

where λ = average number of collisions within an interval
k = values from 0 to 500
e = 2.71828

Again, for the purposes of comparison, two Poisson distributions are generated, one which contains data for the number of accidents per month when photo radar is present (see Figure 14), and another when photo radar is not present (see Figure 15).

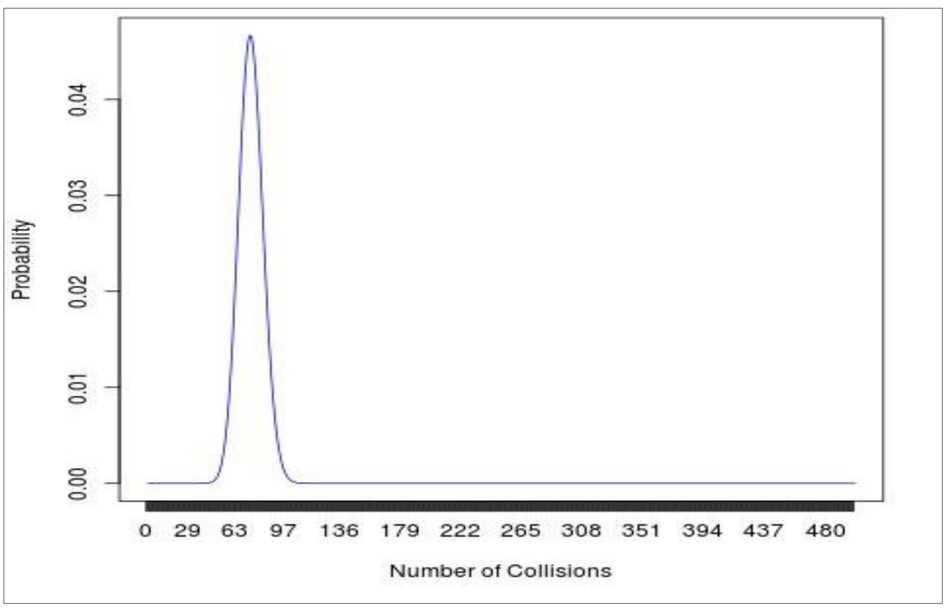

Figure 14. Poisson distribution with mobile photo radar present.

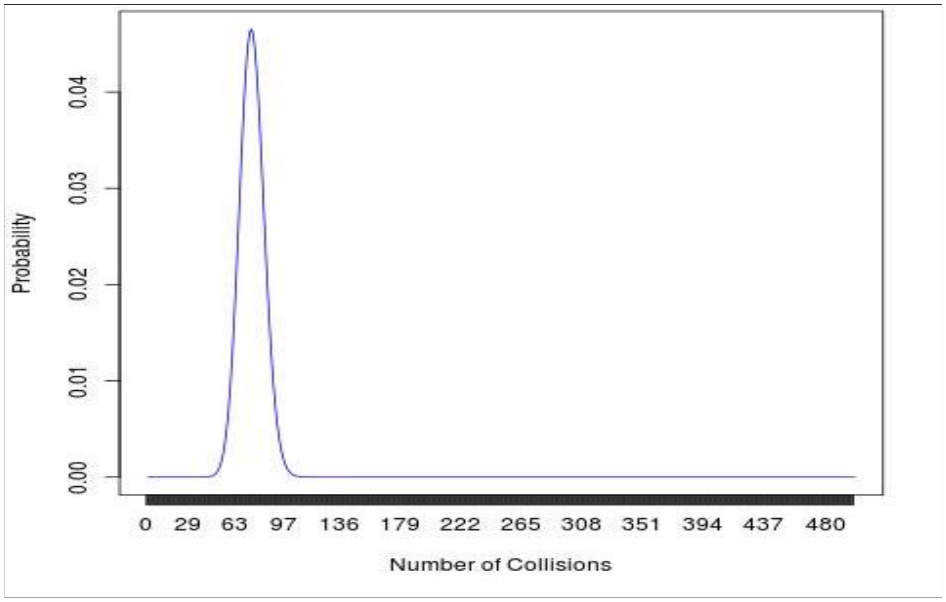

Figure 15. Poisson distribution with mobile photo radar not present.

When analyzing the peak for the two Poisson distributions, the peak probability stands at 73 collisions for the first (we are most likely to see 73 collisions within a month, or a figure quite close to this), while the probability for the second distribution, where photo radar is absent, peaks at 74 collisions. This indicates that the probability of witnessing a significant difference in the number of accidents per month is not high. Also, this serves as an indication that the removal of photo radar did not cause a significant change in the number of accidents, further serving as evidence that there is no link between the presence or absence of photo radar and the number of traffic collisions per month.

6.0 Discussion and Analysis

The purpose of this section is to discuss and analyze information pertaining to my research question, "Does the presence of mobile photo radar have a significant impact on the number of vehicle collisions in Sherwood Park, Alberta?" The section begins with a critique of the quality and methodological rigor of existing literature, which is followed with an exploration of observed versus expected data results from TCLS. It concludes by providing two hypotheses as to why the removal of mobile photo radar did not result in a statistically significant increase or spike in fatalities, injuries, and property-damage-only collisions.

6.1 Methodological Challenges With Existing Mobile Photo Radar Studies

The challenge with most mobile photo radar studies is the methodological quality of the research. No study used the gold standard of experimental design—a randomized control study, which can control for and measure the effectiveness of interventions on a treatment group (Pilkington & Kinra, 2005, p. 331; Wilson et al., 2006, p. 19). Most photo radar studies were observational and used a quasi-experimental design, where the adequacy and appropriateness of comparison and control areas of enforcement were insufficient to make claims about the overall efficacy of mobile photo radar.

All of the studies in the literature review examined photo radar after its implementation in a jurisdiction and all showed a variable range of reported reductions in collisions, injuries, and fatalities (Chen et al., 2000; Gains et al., 2004; Goldenbeld & van Schagen, 2005; Keall et al., 2001; Tay, 2010). When it comes to evaluating the success of mobile photo radar, the application of road engineering measures, additional enforcement efforts, and development of improved traffic flows can influence findings unless variables are controlled for in the study. Without controlling for confounders, the actual effect of mobile photo radar may be much larger or smaller than reported.

It is difficult to compare the findings of this project with those of the above-mentioned studies. This project focused on what happens to collisions following the removal of mobile photo radar, while the studies cited in the literature evaluate the success of photo radar following its introduction and implementation in a specific jurisdiction.

6.2 Observed and Expected Traffic Crash Location System Data Results

Initially, when Strathcona County's TCLS data (R. Anders, personal communication, April 10, 2017) were first examined, it appeared that the absence of mobile photo radar was likely to cause more fatalities, major injuries, minor injuries, and property-damage-only collisions. But once several statistical tests were used, it became clear that the number of traffic collisions in a given month was affected more by weather conditions than other extraneous variables, such as the number of violation tickets issued or fine revenue generated.

This result was confirmed by the Poisson distributions, which showed the peak probability stands at 73 collisions when mobile photo radar is present, while the peak probability for the second distribution, where it is absent, peaks at 74 collisions. The analysis shows that the probability of a significant difference in the number of collisions per month is small. Further, there is no link between the presence/absence of mobile photo radar and the number of traffic collisions per month.

6.3 Halo Enforcement and Spillover Effect

One possible explanation for the results is that mobile photo radar has conditioned the population to reduce speed. Hajbabaie et al. (2011) noted how reductions continue even after the removal of photo radar. They coined the term a "halo effect" (Hajbabaie et al., 2011, p. 125), and it may account for why the number of fatalities, injuries, and property-damage-only collisions were not higher following the removal of mobile photo radar. The halo effect, which Zaal (1994) referred to as a "spillover" (p. ix), may be an advantage over traditional police enforcement as it conditions the population to avoid getting a ticket by lowering driving speeds.

6.4 Increasing Traditional Police Traffic Enforcement

Before mobile photo radar was removed from Sherwood Park, Strathcona County Council committed to hiring additional police officers to offset the perceived general deterrence benefits of automated camera enforcement. Five new peace officers were hired, leading to an increase in the number of traffic enforcement staff on municipal roads (Baxter, 2011). Additional police officers issuing warnings and tickets may have created a form of specific deterrence to persuade motorists to reduce their speeds. As an additional benefit, police officers may have detected and apprehended motorists for other dangerous driving behaviours, including impaired driving, merging too slowly, conducting improper vehicle maintenance, failing to wear seatbelts, and parking a vehicle on the side of the road.

6.5 Summary

The quality of most photo radar research studies reviewed in this project are methodologically poor and none involved a randomized controlled trial. Like this project, the overwhelming majority of studies were observational and used a nonexperimental design, which did not control for extraneous or intervening variables. This project adjusted for the total number of accidents per month by scaling for population to a constant 2001 level. This was done to remove the effects of population growth on the time series.

There are other explanations as to why Strathcona County's removal of mobile photo radar in 2012 did not result in a "rebound" (Chen & Warburton, 2006, p. 675) of fatalities, injuries, and property-damage-only collisions. Increasing traditional police enforcement and the "halo effect" (Hajbabaie et al., 2011, p. 125) may help to explain how discontinuing automated enforcement does not necessarily correlate into a statistically significant increase in collisions. The most likely contributor to collisions appears to be weather. When incidences of photo radar violations pertaining to weather conditions are present in a particular month, the number of traffic collisions in that month increases by 6.569 units—the largest increase of any extraneous variable.

7.0 Recommendations

Based on the literature review as well as data analysis involving a variety of statistical tests, this section provides seven recommendations on how to evaluate the efficacy of mobile radar and makes suggestions for future academic research to expand the existing knowledge base on this topic.

7.1 Recommendations

7.1.1 Recommendation 1: Set benchmarks for all types of collision data captured in the Traffic Crash Location System (TCLS) and collect data for future longitudinal studies

The TCLS was implemented in 2013 and the municipality has a long history of collision data collection stretching back to 1982 (Strathcona County, 2014). These data are invaluable when it comes to conducting longitudinal studies on traffic safety. It is crucial to have a significantly long period of baseline data to make observations and sound judgments about the data. Although 16 years of data and 17,000 unique observations were captured in this study, future researchers conducting studies over a longer period of time will more accurately assess the effects of mobile photo radar enforcement on vehicle speeds, fatalities, injuries, and property-damage-only events.

Strathcona County's (2014) *Traffic Safety Strategic Plan 2020* targets reductions in the average annual rate of combined fatal and major injury collisions, but it does not commit to reducing minor injuries and property-damage-only collisions in order to improve overall traffic safety in the municipality. All types of collisions should be targeted for reductions, not just fatalities and major and minor injuries, as many property-damage-only collisions require law enforcement and emergency services resources, affect traffic flow, and impact the perception of overall traffic safety in the community.

7.1.2 Recommendation 2: Traffic enforcement in Sherwood Park should be weighted more towards specific deterrence than a general deterrence model

Male drivers between the ages of 18 and 19 have the highest fatality rates in the province (Alberta Transportation, 2015, p. 5), and according to Strathcona County's *2015 Traffic Safety Survey*, males reported it was safe to travel 10 km/h or more over the posted speed limit. Quite simply, specific deterrence works by targeting the highest risk scenarios that are at the greatest risk of causing a severe traffic collision.

7.1.3 Recommendation 3: Using public opinion surveys, seek feedback on mobile photo radar as a traffic safety tool

When it comes to traffic law enforcement, a paradox exists. On the one hand, Canadians view speeding as dangerous and associate it with increased risk of collision, injury, and death (EKOS, 2005, p. i). This view is backed by collision data from Alberta Transportation (2015), which show that one in four drivers in a fatal collision (22.8%) and one in 10 drivers in injury crashes (9.3%) were driving at an unsafe speed (Alberta Transportation, 2015, p. 5). On the other hand, many people continue to travel above posted limits, and law enforcement efforts to use photo radar technology to reduce speed are often met with a polarized public reaction (EKOS, 2005, p. 32). Ongoing public opinion surveys are required to understand why speeding is viewed as the primary cause of serious accidents, while speeding activity is ranked the least dangerous driving situation (EKOS, 2005, p. 25). Public opinion surveys may help researchers and public administration officials to understand the causes of the speeding paradox and, more importantly, help to create more effective public awareness messages about the risks and consequences of speeding activities.

Although mobile photo radar has been discontinued in Sherwood Park, Alberta, it is still important to assess public opinion on the technology's usage as a traffic safety tool. While Strathcona County's *2015 Traffic Safety Survey* included open-ended questions on how to address residential speeding concerns, the project recommends the use of the survey provided to solicit direct responses about the use of mobile photo radar and other traffic safety tools, such as speed boards. When it comes to mobile photo radar, it is important to determine whether the public believes the technology is used to increase safety or generate revenue for municipal government.

7.1.4 Recommendation 4: Conduct a time series analysis following the removal of mobile photo radar in a given jurisdiction.

This project appears to be the first of its kind to analyze how the discontinuation of mobile photo radar affects traffic safety in a municipality. Although a plethora of studies revealed the effects of automated enforcement once it had been introduced and operated in a jurisdiction, more research is needed to confirm the findings of this project. Put simply, jurisdictions such as British Columbia, Ontario, and Drayton Valley, Alberta are ideal to test whether the removal of mobile photo radar has resulted in a rebound of collision events.

7.1.5 Recommendation 5: Enforcement Transparency

Public administrators and law enforcement officials should publish the locations of speed traffic enforcement, especially when using mobile photo radar. By highlighting locations and the reasons for their selection, this will assist jurisdictions to defend against accusations that mobile photo radar is being used for revenue generation. Of course, selected locations should be collision-prone areas. If baseline collisions in a specific location fail to drop over a 12-month period, the jurisdiction needs to reconsider mobile photo as an enforcement tool for that area or at least justify why photo radar remains a viable means of enforcement.

Further, municipalities should consider publishing an annual breakdown of where photo revenue is spent. It should be published electronically on a municipal web site and be easily accessible by the public. If violation tickets are mailed, a web link should be added to the violation ticket, envelope, brochure, or a combination thereof, so violators know where traffic revenue is directed by the municipality. As photo radar is a traffic violation, the project recommends that the vast majority of revenue, 70 per cent or more, be directed towards traffic safety capital, traffic safety operations, traffic safety initiatives, and traffic education programs.

7.1.6 Recommendation 6: Further Research on Traffic Enforcement Options

There are a number of traffic enforcement tools available to reduce fatalities, major and minor injuries, and property-damage-only collisions. The reality is that photo radar is only one of the available options. Ongoing research is required so municipalities and law enforcement can evaluate the relative efficacy of different speed reduction tools. For example, when is a speed board more effective than mobile photo radar? Under what specific conditions is photo radar more effective than traditional officer deployment? Additional research, including a matrix of traffic enforcement choices, will allow municipalities to utilize resources in the most effective and efficient manner to enhance overall traffic safety.

7.1.7 Recommendation 7: Improvements to Traffic Collision Location System

Strathcona County should be commended for its investment and usage of its Traffic Collision Location System (TCLS). This project would have not been possible without the valuable data contained within it. However, more data, specifically weather conditions, would be invaluable for future research. Using Environment Canada's weather forecast, data can be entered into the system to help better understand how intervening variables such as rain, snow, and ice influence traffic collisions. The Alberta Motor Association classifies road using the following categories: unreported; closed; covered; partially; and bare. The municipality could adopt these categories or create its own unique terms to describe road conditions.

7.2 Summary

The recommendations in this project are intended to guide Strathcona County's future traffic safety and enforcement efforts as they relate to speeding and the use of mobile photo radar. In addition, it provides jurisdictions that are considering operating, presently operating, or considering discontinuing the operation of mobile photo radar with statistical data on the technology's traffic safety effect. Ultimately, achieving traffic safety is best achieved through ongoing analysis of collision data, collaboration with stakeholders, and research of public opinion attitudes towards existing and new forms of traditional and automated traffic enforcement.

8.0 Conclusion

Traffic collisions are a leading cause of injuries and death (World Health Organization, 2013, p. vii) and present significant health and safety policy issues to elected officials, public administrators, and law enforcement. Speed limits, which are designed to control top speeds, improve traffic safety, and reduce the number of fatalities, are frequently ignored, creating a situation where exceeding the speed limit is a common traffic offense (Tay, 2010, p. 248).

According to Alberta Transportation (2015, p. 5), driving at an unsafe speed was responsible for one in four drivers being in a fatal collision (22.8%) and one in 10 drivers in injury crashes (9.3%). There is a need for government to continue to regulate and monitor speed, and as Wilson et al. (2006) indicated, this responsibility "is not in doubt" (p. 27). What is in doubt is whether mobile photo radar, even after 50 years of development and operational enforcement use, is the right tool to achieve reductions in speed, fatalities, injuries, and property-damage-only collisions.

Automated camera enforcement remain one of the most controversial traffic enforcement tools, even though the technology has been utilized throughout North America, Europe, and Australia, automated speed cameras for over half a century. Literature regarding the safety benefits and efficacy of photo radar to reduce the number of fatalities, injuries, and property-damage-only collisions is varied and inconclusive. In many jurisdictions, mobile photo radar exists as a form of revenue generation as opposed to a traffic safety tool, even if that was not the original intent behind implementing automated camera technology. When this occurs, large jurisdictions, such as British Columbia and Ontario, have removed automated enforcement cameras to address public and political concerns about the technology serving as a "cash cow" (Graney, 2017, para. 9).

Sherwood Park, Alberta, provided an opportunity to evaluate what happens to traffic safety after mobile photo radar is discontinued and to assess whether traffic statistics "rebound" (Chen & Warburton, 2006, p. 675) when automated traffic enforcement is removed from a municipality. The project's findings do not support mobile photo radar as a tool to improve traffic safety by reducing fatalities, injuries, and property-damage-only collisions in Sherwood Park, Alberta. Both the time series analysis and Poisson distribution showed marginal statistical evidence that mobile photo radar has significantly lowered the number of vehicle collisions. On the basis of the data analyzed in the study, automated enforcement cameras have been shown to have insignificant effect on the number of monthly collisions. In fact, weather is a much greater predictor of the frequency of collisions than mobile photo radar, even when the number of speed violations and revenue generation is taken into account.

Research indicates that the number of lives lost in road collisions in Canada has trended downward in recent decades. Canada has reported a decrease in all fatality, serious injury, and total injury categories. Even the total number of fatalities per billion kilometers travelled is the lowest on record (Transport Canada, 2014, p.2). Despite the statistics, many jurisdictions are choosing to increase enforcement activities through the use of automated speed camera technology. Wilson et al. (2006) argued that automated speed enforcement has the capability of being a substantial net revenue-raising activity, blurring the line for the public as to whether the technology is used for safety or fiscal considerations (p. 3). When a lack of transparency, fairness, and accountability exists, pressure will eventually mount to cease mobile photo radar activities regardless of whether or not it appears to reduce collision events.

To conclude, the present body of knowledge on mobile photo radar requires a stronger evidence base to solidify claims about the effectiveness of automated camera speed technology as an enforcement tool.

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Appendix 1: Mobile Photo Radar and Traffic Safety Study

Date: ____

Time Start: ____

[**NOTE: Read Verbal Consent Form before beginning survey]**

Hello. I am conducting research for a study on traffic safety in Sherwood Park.. Can I speak with you for 10 minutes to take part in a brief survey? All of your answers will be held strictly confidential.

Before I begin, I need to know:

A. Do you live in Strathcona County?

Yes	1 (Continue)	**No**	2 (Thanks and End)

B. Are you 18 years of age or older?

Yes	1 (Continue)	**No**	2 (Thanks and End)

C. Which of the following categories comes closest to your age?

18 to 24	1
25 to 34	2
35 to 44	3
45 to 54	4
55 to 64	5
65 or older	6

Broad Perceptions of Traffic Safety

1. I am going to read a list of specific traffic issues to you. Let me know whether or not you think Sherwood Park should concentrate on any of these issues.

	Yes	No	Unsure
Speeding			
Cell phone/texting/distracted driving			
Impaired driving			
Running red lights			
Stop signs			
Aggressive driving/reckless			
Tailgating/following too closely			
Lane changing without signaling			
Jaywalking/pedestrians			

2. I am going to read a list of common traffic collision causes. Tell me what you think are the top two causes of traffic collisions in Sherwood Park.

	Choice 1	Choice 2
Speeding		
Driver inattention/distraction		
Impaired Driving		
Aggressive driving/road rage		
Bad weather		
Road conditions (excluding bad weather)		
Bad drivers/inexperienced drivers		

Traffic volumes/heavy traffic		
Running red lights/stop signs		
Driver fatigue		
Other		
Don't know/no response		

3. Do you believe that there is enough traffic enforcement in Sherwood Park?

Strongly agree	1
Agree	2
Disagree	3
Strongly disagree	4
Not sure	5

Broad Perceptions on Speed

4. From what you have seen, read, or heard, do you think the speed limit on Sherwood Park arterial (major) roads should be higher, remain the same, or be lower?

Higher	1
Remain the same	2
Lower	3
Unsure	4

5. From what you have seen, read, or heard, do you think the speed limit on Sherwood Park residential (neighbourhood) roads should be higher, remain the same, or be lower?

Higher	1
Remain the same	2
Lower	3
Unsure	4

Perceptions on Mobile Photo Radar

6. As you may know, in 2012, Strathcona County discontinued using mobile photo radar. Do you think Strathcona County should bring back photo radar?

Yes	1	**No**	2	**Unsure**	3

7. Do you think roads are safer, less safe, or offer the same level of safety since the removal of mobile photo radar?

Safer	1	**Less safe**	2	**About the same**	3

8. Would you say you are more careful to observe speed limits when driving in other municipalities that have mobile photo radar, like Edmonton and Fort Saskatchewan?

More careful	1	**No difference**	2	**Not sure**	3

9. Do you agree or disagree with the following statement: Mobile photo radar saves lives.

Strongly agree	1
Agree	2

Disagree	3
Strongly disagree	4
Not sure	5

10. Do you agree or disagree with the following statement: Mobile photo radar reduces the number and severity of major injuries involving traffic collisions.

Strongly agree	1
Agree	2
Disagree	3
Strongly disagree	4
Not sure	5

11. Do you agree or disagree with the following statement: Governments use photo radar to generate revenue and not to reduce safety.

Strongly agree	1
Agree	2
Disagree	3
Strongly disagree	4
Not sure	5

12. In general, do you support or oppose the use of mobile photo radar in Sherwood Park?

(Continue to Q13) Support	1
(Thank and end) Oppose	2
Not Sure	3

13. Do you favour the use of mobile photo radar to enforce laws against speeding on arterial roads (major roads)?

Strongly favour	1
Favor	2
Disfavour	3
Strongly disfavour	4
Not sure	5

14. Do you favour use of mobile photo radar to enforce laws against speeding on residential roads (neighbourhood roads)?

Strongly favour	1
Favor	2
Disfavour	3
Strongly disfavour	4
Not sure	5

15. Would you approve or disapprove of mobile photo radar cameras being used in school zones?

Strongly approve	1
Somewhat approve	2
Somewhat disapprove	3
Strongly disapprove	4
Not sure	5

16. Would you approve or disapprove of mobile photo radar cameras being used in construction zones?

Strongly approve	1
Somewhat approve	2
Somewhat disapprove	3
Strongly disapprove	4
Not sure	5

17. Would you approve or disapprove of mobile photo radar cameras being used in locations which have had frequent collisions?

Strongly approve	1
Somewhat approve	2

Somewhat disapprove	3
Strongly disapprove	4
Not sure	5

18. Would you approve or disapprove of mobile photo radar cameras being used in locations solely at the discretion of the RCMP and Strathcona County Enforcement Services?

Strongly approve	1
Somewhat approve	2
Somewhat disapprove	3
Strongly disapprove	4
Not sure	5

19. OBSERVED DATA:

Male	1
Female	2

Thank you very much, this completes the interview.

Verify Phone Number: ____

Time End: ____

Appendix 2: Summary of Total Collisions

Note that the total_populationadjusted variable uses the total number of collisions adjusted for the 2001 population; e.g., in September 2016, the total number of collisions was 49. The population during this year was 70,618. In order to scale the population to the 2001 figure, the total number of collisions are adjusted as per **(49/70618)*47645 = 33.05.**

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
Jan 2001	1	0	3	11	36	50	47645	50
Feb 2001	1	0	0	13	59	72	47645	72
Mar 2001	1	0	0	12	41	53	47645	53
Apr 2001	1	0	1	9	35	45	47645	45
May 2001	1	0	2	13	43	58	47645	58
Jun 2001	1	0	2	12	37	51	47645	51
Jul 2001	1	0	2	14	34	50	47645	50
Aug 2001	1	0	1	12	39	52	47645	52
Sep 2001	1	0	3	24	43	70	47645	70
Oct 2001	1	0	1	17	53	71	47645	71
Nov 2001	1	0	1	11	55	67	47645	67
Dec 2001	1	0	2	24	66	92	47645	92
Jan 2002	1	0	0	17	63	80	47645	80
Feb 2002	1	1	1	10	53	65	47645	65
Mar 2002	1	0	0	7	67	74	47645	74
Apr 2002	1	0	1	19	58	78	47645	78

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
May 2002	1	0	1	14	66	81	47645	81
Jun 2002	1	0	5	13	54	72	47645	72
Jul 2002	1	0	1	14	40	55	47645	55
Aug 2002	1	0	2	8	47	57	47645	57
Sep 2002	1	0	1	9	54	64	47645	64
Oct 2002	1	0	3	23	75	101	47645	101
Nov 2002	1	1	0	24	76	101	47645	101
Dec 2002	1	0	2	22	74	98	47645	98
Jan 2003	1	0	0	27	101	128	51544	118.32
Feb 2003	1	0	0	14	66	80	51544	73.95
Mar 2003	1	0	0	16	70	86	51544	79.49
Apr 2003	1	0	0	11	48	59	51544	54.54
May 2003	1	0	1	19	37	57	51544	52.69
Jun 2003	1	0	0	17	30	47	51544	43.44
Jul 2003	1	0	1	15	38	54	51544	49.92
Aug 2003	1	0	0	18	43	61	51544	56.39
Sep 2003	1	1	1	18	50	70	51544	64.7
Oct 2003	1	0	1	16	52	69	51544	63.78
Nov 2003	1	0	1	27	93	121	51544	111.85
Dec 2003	1	0	0	17	66	83	51544	76.72
Jan 2004	1	0	0	28	112	140	51544	129.41
Feb 2004	1	0	1	13	56	70	51544	64.7

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
Mar 2004	1	0	0	21	50	71	51544	65.63
Apr 2004	1	0	3	9	36	48	51544	44.37
May 2004	1	0	0	22	39	61	51544	56.39
Jun 2004	1	0	1	19	37	57	51544	52.69
Jul 2004	1	1	0	19	30	50	51544	46.22
Aug 2004	1	0	0	10	38	48	51544	44.37
Sep 2004	1	0	1	17	32	50	51544	46.22
Oct 2004	1	0	2	17	65	84	51544	77.65
Nov 2004	1	0	1	16	46	63	51544	58.23
Dec 2004	1	0	0	8	46	54	51544	49.92
Jan 2005	1	0	2	20	67	89	55063	77.01
Feb 2005	1	0	1	9	57	67	55063	57.97
Mar 2005	1	0	0	14	43	57	55063	49.32
Apr 2005	1	0	0	17	36	53	55063	45.86
May 2005	1	0	0	19	46	65	55063	56.24
Jun 2005	1	0	1	18	46	65	55063	56.24
Jul 2005	1	0	0	20	38	58	55063	50.19
Aug 2005	1	0	0	13	40	53	55063	45.86
Sep 2005	1	0	1	28	43	72	55063	62.3
Oct 2005	1	0	1	18	48	67	55063	57.97
Nov 2005	1	0	1	32	70	103	55063	89.12
Dec 2005	1	0	0	29	78	107	55063	92.59

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
Jan 2006	1	0	1	22	50	73	56845	61.19
Feb 2006	1	0	1	18	56	75	56845	62.86
Mar 2006	1	0	0	27	83	110	56845	92.2
Apr 2006	1	0	0	16	40	56	56845	46.94
May 2006	1	0	0	21	43	64	56845	53.64
Jun 2006	1	0	0	24	55	79	56845	66.21
Jul 2006	1	0	0	17	54	71	56845	59.51
Aug 2006	1	1	1	18	42	62	56845	51.97
Sep 2006	1	0	0	28	62	90	56845	75.43
Oct 2006	1	2	1	29	80	112	56845	93.87
Nov 2006	1	0	0	31	120	151	56845	126.56
Dec 2006	1	0	2	39	94	135	56845	113.15
Jan 2007	1	0	6	43	99	148	56845	124.05
Feb 2007	1	0	0	28	94	122	56845	102.26
Mar 2007	1	0	1	19	60	80	56845	67.05
Apr 2007	1	0	1	20	44	65	56845	54.48
May 2007	1	0	0	30	69	99	56845	82.98
Jun 2007	1	0	2	22	64	88	56845	73.76
Jul 2007	1	0	1	17	55	73	56845	61.19
Aug 2007	1	2	0	31	65	98	56845	82.14
Sep 2007	1	0	0	18	55	73	56845	61.19
Oct 2007	1	0	1	22	73	96	56845	80.46

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
Nov 2007	1	0	4	27	100	131	56845	109.8
Dec 2007	1	0	1	38	155	194	56845	162.6
Jan 2008	1	0	0	33	131	164	59409	131.53
Feb 2008	1	0	0	33	125	158	59409	126.71
Mar 2008	1	0	0	17	81	98	59409	78.59
Apr 2008	1	1	0	32	109	142	59409	113.88
May 2008	1	0	0	23	66	89	59409	71.38
Jun 2008	1	0	1	24	58	83	59409	66.56
Jul 2008	1	0	1	17	58	76	59409	60.95
Aug 2008	1	0	0	15	54	69	59409	55.34
Sep 2008	1	0	0	25	65	90	59409	72.18
Oct 2008	1	0	2	22	71	95	59409	76.19
Nov 2008	1	0	1	21	77	99	59409	79.4
Dec 2008	1	0	2	35	146	183	59409	146.76
Jan 2009	1	0	1	22	114	137	61660	105.86
Feb 2009	1	0	0	24	82	106	61660	81.91
Mar 2009	1	0	0	22	117	139	61660	107.41
Apr 2009	1	0	0	18	48	66	61660	51
May 2009	1	0	0	18	57	75	61660	57.95
Jun 2009	1	0	0	24	66	90	61660	69.54
Jul 2009	1	0	0	18	62	80	61660	61.82
Aug 2009	1	0	2	17	56	75	61660	57.95

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
Sep 2009	1	0	2	17	67	86	61660	66.45
Oct 2009	1	0	0	29	78	107	61660	82.68
Nov 2009	1	0	2	13	77	92	61660	71.09
Dec 2009	1	0	3	34	193	230	61660	177.72
Jan 2010	1	0	1	23	106	130	61660	100.45
Feb 2010	1	0	0	14	66	80	61660	61.82
Mar 2010	1	0	2	16	72	90	61660	69.54
Apr 2010	1	0	1	14	48	63	61660	48.68
May 2010	1	0	0	16	65	81	61660	62.59
Jun 2010	1	0	0	16	66	82	61660	63.36
Jul 2010	1	0	2	17	50	69	61660	53.32
Aug 2010	1	0	0	15	65	80	61660	61.82
Sep 2010	1	0	1	22	73	96	61660	74.18
Oct 2010	1	0	0	15	79	94	61660	72.63
Nov 2010	1	0	0	22	120	142	61660	109.72
Dec 2010	1	0	0	27	169	196	61660	151.45
Jan 2011	1	1	2	39	183	225	64733	165.61
Feb 2011	1	0	0	17	101	118	64733	86.85
Mar 2011	1	0	0	16	86	102	64733	75.07
Apr 2011	1	0	0	15	59	74	64733	54.47
May 2011	1	0	0	20	50	70	64733	51.52
Jun 2011	1	0	1	20	58	79	64733	58.15

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
Jul 2011	1	0	0	17	43	60	64733	44.16
Aug 2011	1	0	0	18	49	67	64733	49.31
Sep 2011	1	0	1	13	48	62	64733	45.63
Oct 2011	1	0	0	18	62	80	64733	58.88
Nov 2011	1	0	0	11	86	97	64733	71.39
Dec 2011	1	0	0	20	78	98	64733	72.13
Jan 2012	1	0	2	20	79	101	65465	73.51
Feb 2012	1	0	1	10	81	92	65465	66.96
Mar 2012	1	0	0	14	65	79	65465	57.5
Apr 2012	1	0	1	13	62	76	65465	55.31
May 2012	1	0	1	9	51	61	65465	44.4
Jun 2012	1	0	1	15	49	65	65465	47.31
Jul 2012	1	0	2	9	59	70	65465	50.95
Aug 2012	1	0	0	14	47	61	65465	44.4
Sep 2012	0	0	0	19	62	81	65465	58.95
Oct 2012	0	1	2	28	97	128	65465	93.16
Nov 2012	0	0	1	31	141	173	65465	125.91
Dec 2012	0	0	1	13	115	129	65465	93.89
Jan 2013	0	0	0	28	124	152	65465	110.62
Feb 2013	0	0	0	11	60	71	65465	51.67
Mar 2013	0	0	0	13	112	125	65465	90.97
Apr 2013	0	1	2	15	54	72	65465	52.4

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
May 2013	0	0	0	29	60	89	65465	64.77
Jun 2013	0	0	0	12	61	73	65465	53.13
Jul 2013	0	0	0	11	30	41	65465	29.84
Aug 2013	0	0	1	15	50	66	65465	48.03
Sep 2013	0	1	2	21	44	68	65465	49.49
Oct 2013	0	0	1	23	63	87	65465	63.32
Nov 2013	0	0	1	27	150	178	65465	129.55
Dec 2013	0	0	1	26	129	156	65465	113.54
Jan 2014	0	0	0	23	107	130	65465	94.61
Feb 2014	0	1	1	18	104	124	65465	90.25
Mar 2014	0	0	0	18	107	125	65465	90.97
Apr 2014	0	0	1	12	68	81	65465	58.95
May 2014	0	0	1	13	61	75	65465	54.58
Jun 2014	0	0	2	14	75	91	65465	66.23
Jul 2014	0	0	0	19	79	98	65465	71.32
Aug 2014	0	0	0	16	68	84	65465	61.13
Sep 2014	0	0	0	25	76	101	65465	73.51
Oct 2014	0	0	1	31	83	115	65465	83.7
Nov 2014	0	0	2	29	152	183	65465	133.19
Dec 2014	0	0	6	32	115	153	65465	111.35
Jan 2015	0	0	3	39	117	159	68782	110.14
Feb 2015	0	0	2	29	117	148	68782	102.52

Date	Photo radar	Fatal	Major	Minor	Property damage only	Total	Population	Total (population adjusted for 2001)
Mar 2015	0	0	3	21	80	104	68782	72.04
Apr 2015	0	0	1	15	55	71	68782	49.18
May 2015	0	0	2	24	71	97	68782	67.19
Jun 2015	0	0	1	29	69	99	68782	68.58
Jul 2015	0	0	6	22	52	80	68782	55.42
Aug 2015	0	0	1	23	57	81	68782	56.11
Sep 2015	0	1	0	25	77	103	68782	71.35
Oct 2015	0	0	2	19	49	70	68782	48.49
Nov 2015	0	0	0	30	87	117	68782	81.05
Dec 2015	0	0	0	38	107	145	68782	100.44
Jan 2016	0	0	0	28	98	126	70618	85.01
Feb 2016	0	0	1	25	67	93	70618	62.75
Mar 2016	0	0	0	20	67	87	70618	58.7
Apr 2016	0	0	2	17	38	57	70618	38.46
May 2016	0	0	3	29	63	95	70618	64.1
Jun 2016	0	0	5	27	62	94	70618	63.42
Jul 2016	0	0	5	16	57	78	70618	52.63
Aug 2016	0	0	1	11	56	68	70618	45.88
Sep 2016	0	0	1	14	34	49	70618	33.06

Appendix 3: Cross Correlation Results

Lag	Correlation
-19	0.14
-18	0.24
-17	0.13
-16	0.14
-15	-0.06
-14	-0.15
-13	-0.18
-12	-0.28
-11	-0.13
-10	0.02
-9	0.03
-8	0.16
-7	0.21
-6	0.06
-5	0.21
-4	-0.02
-3	-0.03
-2	-0.16
-1	-0.25
0	-0.29
1	-0.13
2	-1.03
3	0.03
4	0.2
5	0.16
6	0.22
7	0.19
8	0.14
9	0.06
10	-0.04
11	-0.13
12	-0.16
13	-0.07
14	-0.02
15	0.08
16	0.14
17	0.17
18	0.16
19	0.13

Appendix 4: Regression Results

Pooled Regression **RSS = 133507**

```
Call:
lm(formula = total[92:189] ~ population[92:189])

Residuals:
    Min      1Q Median      3Q     Max
-58.77 -25.61 -11.27  20.14 125.83

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)         175.335450  81.432132   2.153   0.0338 *
population[92:189]  -0.001154   0.001251  -0.922   0.3586
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 37.29 on 96 degrees of freedom
Multiple R-squared:  0.008786,      Adjusted R-squared:  -0.001539
F-statistic: 0.851 on 1 and 96 DF,  p-value: 0.3586
```

Regression A (Photo Radar Present) **RSS = 71240.68**

```
Call:
lm(formula = total[92:140] ~ population[92:140])

Residuals:
     Min       1Q  Median       3Q      Max
-43.652 -22.356 -12.356   8.701 136.701

Coefficients:
                      Estimate Std. Error t value Pr(>|t|)
(Intercept)         384.402620 177.317761   2.168   0.0353 *
population[92:140]  -0.004574   0.002822  -1.621   0.1117
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 38.93 on 47 degrees of freedom
Multiple R-squared:  0.05294,       Adjusted R-squared:  0.03279
F-statistic: 2.627 on 1 and 47 DF,  p-value: 0.1117
```

Regression B (Photo Radar Absent) **RSS = 55249.77**

```
Call:
lm(formula = total[141:189] ~ population[141:189])

Residuals:
     Min      1Q  Median      3Q     Max 
-69.218 -26.491  -0.491  18.782  72.782 

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)  
(Intercept)        361.398301 155.668488   2.322   0.0246 *
population[141:189]  -0.003837   0.002315  -1.658   0.1040  
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 34.29 on 47 degrees of freedom
Multiple R-squared:  0.05524,	Adjusted R-squared:  0.03514 
F-statistic: 2.748 on 1 and 47 DF,  p-value: 0.104
```