The impact of red-light cameras on the safety of intersections with signals in Ottawa

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I. Introduction and Motivation

The purpose of red-light cameras is to reduce the number of drivers who run red lights, and correspondingly, the number of traffic accidents associated with red-light running [1]. This is important because side collisions, the most common type of accident associated with red-light running, are considered the most severe type of intersection crash [1]. According to a study done in the United States, in 2014 alone intersection-related crashes accounted for "43% of all police-reported crashes" [2]. Over 55,000 serious injuries and 7,000 deaths occurred as a result of these accidents [2]. It can be seen that intersection crashes, especially those related to red-light running, can have drastic and horrific consequences for those involved.

In Ottawa, the number of red-light cameras has been slowly increasing over the years. At the end of 2018, the city had 54 red-light cameras installed [3]. According to the city of Ottawa's website, that number is currently 75 [4]. The city of Ottawa's website states that the purpose of these cameras is to "improve aggressive driving behaviour" and to benefit from the continuation of improved driving habits that spreads into intersections without cameras [4].

Although the installation of red-light cameras should reduce the need for police patrol intersections and increase operational efficiency through the use of automated enforcement technologies [5], the cost of operating red-light cameras across the Ottawa region still cost the city $1.916 million in 2019 [4]. This cost includes start-up costs, engineering, equipment purchases, installation, maintenance, and other operating costs [4]. However, because police are less likely to need to enforce red-light running in these intersections, there is a lower risk of endangering other drivers, cyclists, and pedestrians while chasing offenders, as well as allowing them to focus on other enforcement needs [4].

The purpose of this study is to try to determine whether the presence of red-light traffic cameras in Ottawa have any effect (positive or negative) on the safety of the intersection at which they are installed. Only by showing that red-light cameras do in-fact increase the safety of an intersection can it be said that these machines are worth the cost.

To accomplish this, this study will be using three data sets from the Open Ottawa website.

The first type of data used will by the 5 Red-Light Camera Violations data sets (from 2015 to 2019). These data sets include attributes such as the intersection where the red-light camera is located, what year the camera was installed, and the total number of violations for the year [6]. The second attribute is important because it will allow this study to show whether red-light cameras decrease traffic accidents in their vicinity by comparing the number of accidents before and after the installation of a red-light camera. This study will also compare the number of accidents in an intersection with a red-light camera to those in an intersection without.

The second type of data comes from the Traffic Collisions by Location 2015 to 2019 data set. This data set includes the location of the collisions, the total collisions at those intersections in each year, as well as the cyclist and pedestrian collisions at those intersections in each year [7]. This data set will be used to track the number of collisions at specific intersections as new red-light cameras are installed across the Ottawa region.

The third type of data comes from 5 Tabular Transportation Collison Data sets (2015-2019). These datasets include information about the road conditions and environment conditions at the time of the collision (for instance if it was dark outside and the road was icy) as well as what type of impact occurred during the accident (rear-end collision or angle collision) [19]. This information will be used to exclude external factors that could have caused the traffic accident.

To determine whether there is a correlation between red-light cameras and the number of traffic accidents in Ottawa, this study will be using the Python library called Pandas to analyze the data within the three different types of data sets. The matplotlib library will then be used to visualize the data to answer the following questions:

1. Is there a correlation between the number of red-light camera traffic violations and the number of accidents that occur at an intersection with a red-light camera?
2. Do the number of rear-end and angle collisions decrease or increase after a red-light camera is installed?
3. Is an intersection with a red-light camera safer when compared to a similar intersection without a red-light camera?

The significance of this study is that it will analyze the safety effects of red-light traffic cameras in Ottawa. This is important for two reasons. Firstly, a study of this type has not been done in Ottawa before meaning that this study will fill a gap in the literature. Secondly, this information is important to obtain because there seems to be some conflicting information regarding the usefulness of red-light cameras. For example, a meta-analysis on the effects of red-light cameras on crashes in 2009 showed that according to certain studies, the installation of red-light cameras leads to "an overall increase in the number of crashes by about 15%" [1]. A study in 2022 on the safety effects of red-light cameras in Arlington, Texas concluded that, on average, the number of crashes at intersection with red-light cameras was higher than at intersections without [5].

On the other hand, it seems that most of the research available shows that red-light cameras reduce the number of crashes. A study done in 2019, for instance, stated that red-light cameras "tend to reduce total crashes by 12%" [8]. They also reduce "total right angle crashes by 24%" [8].

However, the same 2019 study also showed that red-light cameras could have further negative effects. In the study, the presence of a red-light camera at an intersection saw an increase of rear-end collisions by 32% [8]. This is because red-light cameras have been shown to cause behavioral changes in drivers approaching an intersection resulting in sudden braking when the light turns yellow, which therefore results in an increase of rear-end collisions at intersections with red-light cameras [9].

This study will analyze data associated with red-light traffic cameras in Ottawa and will try to answer the question of whether red-light cameras improve the overall safety of intersections in Ottawa or not.

1. LITERATURE REVIEW AND COMPARATIVE ANALYSIS

Paper [1]:

This study looks at the effectiveness of red-light cameras as a safety measure. The study questions if red-light cameras affect the overall number of right-angle or rear-end collisions, and whether there is a change in the overall severity of the crashes after a red-light camera is installed. The study tries to find out how red-light cameras affect intersection crashes. It also looks at spillover effects, which is when red-light cameras affect the number of crashes at intersections close by that do not have red-light cameras installed.

This study has the following strengths:

This study thoroughly examines the results of 21 existing studies, including looking at which studies were affected by the regression to the mean (when red-light cameras are placed at intersections that have had large amounts of collisions) and spillover effects. The study also looks at publication bias (where studies with

insignificant or unexpected results do not get published) and outlier bias, and how they might affect the results of existing research. By doing a thorough, critical, examination of existing research results, this study is able to come to a strong conclusion.

The weaknesses of this study are as follows:

The biggest weakness of this study is that it was done in 2009. Recent advances in technology may mean that the same study done on more recent publications may find different results. It means it can also not account for technology drivers have added to their cars such as Apple or Google Maps which now warn the driver well ahead of an intersection that there is a red-light camera ahead.

Paper [2]:

In the United States, red-light running is a common traffic violation that can have fatal consequences for all parties involved [2]. One of the measures put in place to prevent red-light running in American cities is the addition of red-light cameras at intersections with signal lights. This study examines two groups of cities, those with red-light cameras and those without, and compares the trends in fatal crashes per capita. This study also examines how turning on or turning off red-light cameras in different cities affects the trends of fatal crashes. The results show that for both cities with red-light cameras, and for those without, turning on red-light cameras decreased the number of fatal crashes at intersections, and turning off red-light cameras increased the number of fatal crashes at intersections.

This study has the following strengths:

This study is the first study to show that removing red-light cameras in areas that already have them increases the number of fatal crashes. The study also analyzed a good size pool of data. The data used was taken from 90 American cities (57 with red-light cameras and 33 without) across 23 consecutive years (1992-2014).

The weaknesses of this study are as follows:

One of the weaknesses of this study is that it concentrates on the number of fatal crashes. The study, therefore, does not make note of whether or not the presence of red-light cameras reduces the total amount of crashes. The study was also done in the United States between the years 1992 and 2014 which means it does not include recent data. This is a weakness because rapid changes in technology (for instance the advent of mobile map applications that warn a driver about upcoming red-light cameras) could mean that if the same study was done today, it may yield different results.

Paper [5]:

Although red-light cameras have proven safety benefits, red-light cameras are a politically debated issue due to concerns around privacy and financial issues. In order to assist policy debates, this study analyses the number of crashes in Arlington, Texas from 2013 to 2016 to understand the consequences of red-light camera deactivation.

This study has the following strengths:

This study uses Moran's I statistic and Geographically Weighted negative Binomial Regression approach instead of the Empirical Bayesian approach or Poisson regression, both of which have been used in previous research but have limitations when it comes to studying the effects of red-light deactivation. This new approach, therefore, can make up for shortcomings in existing research. This study also fills a gap in existing research by providing not only data on a location that has previously been unstudied but also focusing on an area of research (the consequences of the removal of red-light cameras) that has previously been under-researched.

The weaknesses of this study are as follows:

The biggest weakness of this study is the time period. Although the study covers the time between 2013 and 2016, it only covers 20 months before and 20 months after the red-light cameras were deactivated. The study does not consider whether or not the sudden deactivation of red-

light cameras caused behavioural changes that might change as time goes on and drivers get used to the red-light camera being there. A study done in the same area over a longer period of time, therefore, may reveal different results.

Paper [8]:

Around the world, red-light running accounts for a large portion of the crashes that occur at intersections. To try and combat this, countries such as the U.S. and Britain have installed red-light cameras in different cities. Red-light cameras are supposed to decrease the number of fatal crashes at an intersection and make driving a safer experience overall, but recent studies have found that red-light cameras may increase the amount of rear-end crashes. This study looks at 18 new studies done on red-light cameras in order to update the research on safety effectiveness.

This study has the following strengths:

This study looks at the safety effectiveness of red-light cameras. In order to do this, the study includes a comprehensive literature review of 18 articles from 2012-2016 found in an international database called Scopus that had previously not been researched. This allows the study to look at existing research from around the world and not be limited to a specific country or city. Another strength of this study is that it looks at studies that show that red-light cameras have positive safety effectiveness as well as studies that show the opposite. By reviewing both sides of the argument equally, this study is able to refrain from having too much bias in its results.

The weaknesses of this study are as follows:

The major weakness of this study is that the research it reviews is from 2011 to 2016. This means that the research is not very recent and may be getting outdated. The study itself mentions that the improving technology of red-light cameras may be a reason why some of the more recent articles the study reviews tended to have a more favourable view of red-light camera safety effectiveness. Since 2016, technology in all areas has made rapid changes and it stands to reason that red-light cameras may have also had upgrades and improvements.

Paper [9]:

Despite red-light cameras being added to intersections with the purpose of increasing the safety of the intersection, studies have shown that intersections with red-light cameras have an increase in rear-end collisions compared to those without. This study uses a combination of real-world observation, driving simulator-based observations, and the data from 63 participants to look at the behavioural responses of drivers to speed and red-light cameras in order to try and find the root cause of the increase in rear-end collisions.

This study has the following strengths:

Instead of just looking at the number of crashes at an intersection in an area, this study looks at how drivers behave to the addition of a red-light camera at an intersection. This means that this study takes a different, unique, approach to studying the effectiveness of red-light cameras when compared to other existing studies. The study's use of a semi-automated video analysis software allows the study to analyze drivers' behaviour at a micro-level with high accuracy. Other existing studies may use human observers or radars, both of which are unable to achieve the same level of detail that this study is able to accomplish because of the software.

The weaknesses of this study are as follows:

One of the weaknesses of this study is that it does not look at driver behaviour over a long period of time and therefore the results of this study cannot take into consideration the fact that as drivers get used to a red-light camera being in an intersection their behaviour may change. In terms of the real-world observations, the study only looks at two intersections. This means that the study is limited because its results can only reflect two of the many different intersections drivers may encounter in their everyday life.

Paper [10]:

To evaluate the safety effectiveness of red-light cameras on red-light violations leading to crashes, this study uses the Bayes approach to analyze data from 5 intersections with red-light cameras and 14 intersections without. It observes a significant decrease in crashes following the installation of the cameras, especially for angle and turn crashes, but there was an increase in rear-end crashes over time.

This study has the following strengths:

The study compares two types of intersections with similar traffic volumes, patterns, and occurrences of crashes. The study took place over a period of 5 years, allowing for more comprehensive data to be collected, including before and after the installation of red-light cameras in 2010. It also takes into consideration the severity of the crashes along with the types of crashes, the traffic volume, and the characteristics of the intersections that may influence the overall safety of the intersection.

The weaknesses of this study are as follows:

This study focuses on the effects of red-light cameras in Miami Beach, Florida, so it is possible that the types and frequencies of crashes may change in other regions. The study also only looks at certain types of intersections with similar characteristics, so other types of intersections may also have different results for the number or types of crashes.

Paper [11]:

This study discusses the effects of installing red-light cameras at intersections and their effects on the surrounding area (overflow). It performs safety evaluations on the intersection with the red-light camera and intersections without red-light cameras nearby. It was found that there was an increase in left-turn crashes and an increase in rear-end crashes. There were also some moderate spillover benefits in the surrounding area.

This study has the following strengths:

The study uses several different techniques to analyze the data collected. The Before-After Empirical Bayes method is used for the interactions observed, the Kernel Density Estimation is used to cluster crashes to identify the differences in the likeliness of crashes over time.

The weaknesses of this study are as follows:

The study only directly collects data from Orange County, restricting its scope to the area, so it does not consider other areas that may have different results. The time covered by the experiment was also quite short, a longer observation time may offer more conclusive results.

Paper [12]:

Dilemma zones are the areas near intersections where drivers must decide whether they will cross the intersection during a yellow light. This study discusses the presence of red-light cameras and traffic signal countdown timers and the effect they have on drivers' decisions in these dilemma zones.

This study has the following strengths:

The study uses previous studies as a basis for the lengths of the dilemma zones, then used binary logistic regression to better define the boundaries of the distance where drivers have the time to make a choice about stopping or continuing through the intersection.

The weaknesses of this study are as follows:

The study only observes 2 intersections, one with red-light cameras, and one with traffic signal countdown timers, where observations were made when each respective type of signal was on and off. Therefore, while the study collected 619 observations, it is only able to analyse a very limited set of driver behavior data, and the data collected may not reflect drivers' behavior in dilemma zones elsewhere.

Paper [13]:

This study discusses the effectiveness of installing red-light cameras at intersections in deterring traffic violations, and the number and types of accidents that occur in and around that intersection. It is a summary of a systematic

review of 41 studies, where the studies with similar outcomes were pooled, and all other studies were described. It was found that red-light cameras have a positive effect on reducing crashes and traffic violations, with differences in effectiveness depending on the type of accident.

This study has the following strengths:

The study narrows down the pool of potential studies to review using various selection criteria, including the type of experiment done, title and abstract screening, and full-text reviews. It uses the EMMIE framework to assess the effectiveness of red-light cameras as discussed in the various studies to expand on the Cochrane systematic review done in 2005. It provides very a very in-depth review of the data from the different studies, including variables and other factors involved with the implementation of the red-light cameras.

The weaknesses of this study are as follows:

The article only looks at studies up to June 2015, so new research that has been done in the intervening years will not have been included in the review. It also only uses a very specific set of studies for the review, so it may have missed some studies with more varied results. It also did not account for spillover or regression to the mean or the number of other variables (confounders) that were discussed in the studies.

Paper [14]:

Researchers observe 8 intersections in Alabama to determine the effects of the presence of red-light cameras on drivers' decisions as they approach the intersection during yellow and red lights. In particular, the study focuses on the "Green Extension", and the reduction in entry time during the interval in-between the yellow and red light. It aims to answer 2 hypotheses: 1. that drivers will be more likely to stop in this interval (rather than proceed) because of their awareness of the red-light camera; and 2. that drivers will be less likely to use the yellow-light interval to cross the intersection. The researchers found that more drivers chose to cross the stop line during the yellow light rather than stop at the intersections without red-light cameras compared to the intersections with red-light cameras.

This study has the following strengths:

The study helps to determine the time range during which drivers were more likely to enter the intersection during the yellow-light interval in the 2 types of intersections using a very simplistic method. All the steps are well recorded, so the study could be replicated if needed, or a similar method can be used for other studies.

The weaknesses of this study are as follows:

The study acknowledges that the equipment used for the study has some limitations. The stopwatches were started and stopped manually, adding an element of human error through reaction time to the experiment. The video cameras that were used to record the cars going through the intersections could not measure the speed and acceleration of the vehicles entering the intersection, so it is not possible to predict whether a car would go or stop when nearing the intersection.

Title	Author(s)	Year	Data/ data sets	Methods/Approach	Outcomes
Red light for red-light cameras? [1]	Alena Erke	2009	1. The results of 21 studies 2. 81 effect estimates	1. Log-odds method of meta analysis 2. Literature review	The study found that red-light cameras increase the number of crashes at an intersection compared to an intersection without red-light cameras by 60%. The study also found that red-light cameras can cause spillover effects which can increase the number of crashes in intersections close by that do not have a red-light camera installed. The study concludes that overall, red-light cameras are not a successful safety measure.
Effects of turning on and off red light cameras on fatal crashes in large U.S. cities. [2]	Wen Hu and Jessica B. Cicchino	2017	1. Trends in fatal red-light crashes for 57 U.S cities with red-light cameras installed between 1992 and 2014. 2. Trends in fatal red-light crashes for 33 U.S cities that do not use red-light cameras.	Used Poisson regression to examine how turning on and off red-light cameras affected the number of fatal car crashes.	The study found that for both cities with and without red-light camera programs, turning on red-light cameras decreased the number of fatal crashes at intersections, and turning off red-light cameras increased the number of fatal crashes at intersections.
Assessing the safety effect of red-light camera deactivation: a geographically weighted negative binomial regression approach. [5]	Jianling Li & Alan Ricardo da Silva	2022	1. Number of crashes in Arlington, Texas from 2013-2016 at intersections with red-light cameras versus the number of crashes at intersections without red-light cameras. 2. Number of crashes in Arlington, Texas from 2013-2016 at intersections with red-light cameras for 20 months before and after the red-light camera was deactivated.	Moran's I statistic and Geographically Weighted negative Binomial Regression approach	Over the period of time the study covered, not only did the total number of crashes rise within the city of Arlington but the study also found that the number of crashes was higher in intersections where red-light cameras had been deactivated than anywhere else in the city.
Red light cameras revisited. Recent evidence on red light camera safety effects. [8]	Charles Goldenbeld, Stijin Daniels and Govert Schermers	2019	1. 18 new studies on red-light cameras 2. Literature from the international database Scorpus over the period of 2012-2016	1. Literature review 2. Meta-analysis using JASP	The study found that red-light cameras do reduce right-angle crashes but that they also increase the number of rear-end crashes. The study also found that speed red-light cameras are more effective in reducing the number of crashes at an intersection than red-light cameras.
Drivers' behavioral responses to combined speed and red light cameras. [9]	Polders, Evelien, et al	2015	1. Real-world observations (video recordings at two intersections)	1. Monte Carlo Simulation 2. T-Analyst (2014) 3. Pearson's chi-square tests 4. Independent *T*-tests	The study found that red-light cameras reduce the number of drivers who run a red or yellow light. The study also found that the odds of a rear-end collision for an

			2. Driving simulator-based observations 3. Data from 63 participants		intersection with a red-light camera are higher than an intersection without, but that adding a warning sign can reduce those odds.
A before-after full bayes multivariate intervention model to estimate the safety effectiveness of red light cameras. [10]	Angela E. Kitali, Fabio Soto, Priyanka Alluri, and Md Asif Raihan	2021	1. 5 intersections with red-light cameras 2. 14 intersections without red-light cameras 3. Crash data from 2008-2013	SignalFourAnalytics used to identify and extract crash data. Poisson-gamma statistical model used to determine effectiveness of red-light cameras.	The study found that there were fewer types of crashes after the installation of red-light cameras at intersections. There was generally a decrease in angle and turn crashes, but an increase in rear-end crashes.
Evaluation and spatial analysis of automated red-light running enforcement cameras. [11]	Mohamed M.Ahmed and Mohamed Abdel-Aty	2015	1. Crash data from 25 intersections with red-light cameras 2. Crash data from 50 intersections in the surrounding area for spillover effects	Using the before-after Empirical Bayes method to compare the crash data from intersections before and after the red-light cameras were installed. Poisson test performed on approaches.	Reduction in angle and right-turn crashes, increase in rear-end crashes. Significant spillover effect on non-rear-end crashes.
Effect of speed/red-light cameras and traffic signal countdown timers on dilemma zone determination at pre-timed signalized intersections. [12]	Omar Almutairi and Heng Wei	2021	1. 2 intersections: 1 with red-light cameras and 1 with countdown timers 2. Both intersections are installed with a countdown timer 3. Data collected over 2 days	Uses binary logistic regression to determine the boundary lines of dilemma zones using the probability of a driver stopping and the probability of running a yellow-light.	Significantly more drivers will stop with the presence of the red-light camera compared to only the countdown timer or neither installed.
Red light camera interventions for reducing traffic violations and traffic crashes: A systematic review. [13]	Ellen G. Cohn, Suman Kakar, Chloe Perkins, Rebecca Steinbach, Phil Edwards	2020	1. 41 studies related to red-light cameras' effects on red-light running and traffic violations	Assessed heterogeneity using chi-square tests at a 5% level of significance, and the I-squared statistic. Used EMMIE to assess effectiveness.	The study found that red-light cameras lower red-light violations and are associated with a 20% decrease in overall crashes, but an increase of 19% in rear-end crashes.
Effects of red light cameras on driver's stop/go decision: Assessing the green extension hypothesis. [14]	Fatemeh Baratian-Ghorghi, Huaguo Zhou, Ana Franco-Watkins	2017	1. 4 intersections with red-light cameras in Opelika, Alabama 2. 4 intersections without red-light cameras in Auburn, Alabama 3. Observed traffic between 15:30–18:30	Used cross-sectional analysis to determine how red-light cameras affected drivers' behaviour across 8 intersections. Response data was collected from 2391 drivers using video cameras placed at each intersection. The time between the yellow and red light was recorded 1613 times.	More drivers chose to cross the stop line during the yellow light rather than stop at the intersections without red-light cameras compared to at the intersections with red-light cameras.

III. GAP ANALYSIS

All 15 articles review and study the effects of red-light cameras on reducing red-light running and the number of crashes at an intersection with signals, on increasing the safety of intersections, as well as how red-light cameras affect a driver's behaviour and decisions.

Studies [1], [8], [11], and [13] all include a detailed literature review of existing research on the effects of red-light cameras.

Studies [14] and [9] both look at assessing how red-light cameras affect a driver's behaviour and decision-making process. Both studies [14] and [9] use cameras to record cars at an intersection, but while study [14] looks at 4 intersections with red-light cameras and 4 without, study [9] only looked at 2 intersections. Unlike study [14], though, not only did study [9] use a semi-automated video analysis software when analyzing the intersection video (which according to the authors of the study allows them to analyze drivers' behaviour at a micro-level with high accuracy), some of the primary data from study [9] came from driving simulator- based observations from 63 participants. While both studies came to similar conclusions (that red-light cameras decrease the number of vehicles that run red and yellow lights), neither study was conducted long-term to determine if a driver's behaviour changes as he or she gets used to the presence of a red-light camera at an intersection.

Studies [2] and [5] look specifically at what happens when a red-light camera at an intersection is deactivated. Study [2] is a bigger study, looking at the trends in fatal red-light crashes for 57 cities in the U.S with red-light cameras and 33 without from 1992 to 2014 and uses Poisson regression to analyze the data found. Study [5] on the other hand looks at the number of crashes in Arlington, Texas from 2013 to 2016, comparing both intersections with red-light cameras and those without as well as looking at how the number of crashes changed 20 months prior to and after the deactivation of a red-light camera and uses Moran's I statistic and Geographically Weighted negative Binomial Regression approach to analyze the data. Both studies [2] and [5] come to the same conclusion: that the number of crashes increases at an intersection after the red-light camera is deactivated.

One common factor between studies [8], [9], [10], [11], and [13] is that the chances of rear-end crashes increasing compared to intersections without red-light cameras. There was also generally a lower chance of angle or right-/left-crashes in intersections with red-light cameras compared to those without. The only study to look at why this potentially happens is [9], in which drivers' behaviors and responses when approaching intersections with red-light cameras tend towards stopping suddenly during a yellow light.

One of the gaps in this literature review is that none of the 15 studies reviewed look at the impact technology can have on the number of crashes at an intersection with a red-light camera. Study [9] concludes that a warning sign can reduce the odds of a rear-end collision in an intersection with a red-light camera and study [12] finds that there's a small decrease in overall crashes if an intersection with a red-light camera has a count-down timer compared to an intersection with a red-light camera that has no timer. Neither study, however, looks at how technology (such as mobile map applications like google maps) that warn drivers of red-light cameras before they approach an intersection affects the number of crashes at an intersection with red-light cameras.

Another gap in this literature review is that the majority of the 15 studies look specifically at the United States, and none of them investigate the effects of red-light cameras in Canada, or more specifically, Ottawa, Ontario. Study [5] claims to have filled in a gap in existing research by researching a previously unstudied location (Arlington, Texas). Since none of the studies look at Ottawa, researching the effects of red-light cameras in this city would fill in a gap in the existing literature.

IV. PROBLEM IDENTIFICATION

This project would like to solve the following questions for the city of Ottawa:

- Does the total number of fatal crashes at intersections with red-light cameras decrease in comparison to intersections without red-light cameras?
- Does the number of crashes at an intersection decrease once a red-light camera has been installed?
- Does the number of crashes at an intersection with a red-light camera change over time as drivers become habituated to the presence of the red-light camera?

A. Hypothesis:

The overall number of crashes will decrease once a red-light camera is installed when compared to an intersection with a red-light camera, but as time goes on the number of crashes will increase once drivers adapt to the presence of the red-light camera.

B. Main Objective:

- To determine if the safety benefits of red-light cameras are worth the cost of operation per year ($1.916 million in 2019 [4]) in the city of Ottawa.

C. Sub-objectives:

- To measure the total number of crashes that occur at an intersection with a red-light camera in Ottawa immediately before and after the red-light camera is installed.
- To ascertain if the total number of crashes at an intersection with a red-light camera in Ottawa changes over time after the red-light camera is installed.
- To look at the total number of crashes at an intersection with a red-light camera in Ottawa when compared to a similar intersection (speed limit, lane types within the intersection) in Ottawa that does not have a red-light camera.

D. High-level Plan:

- Gather data from three different types of datasets:
  - Red-Light Camera Violations data sets from 2015 to 2019 [6]
  - Traffic Collisions by Location data sets from 2015 to 2019 [7]
  - Tabular Transportation Collison Data 2015- 2019 [19]
- Use these data sets to find a correlation between red-light cameras and the number of traffic accidents in Ottawa by researching the immediate before and aftereffects of the installation of a red-light camera, the long-term effects of a red-light camera installation, and the difference between similar intersections (speed limit and lane types) with and without red-light cameras.
  - Use the Python library called Pandas to analyze the data within the two data sets
  - Use the Python library called matplotlib to map out the data in linear regression models and bar charts

V. DATA COLLECTION AND SAMPLING

This project is using secondary, quantitative data from the website Open Ottawa. The data will be downloaded in CSV format and formatted using the Python library called Pandas. This will include getting rid of columns and instances not needed for the data analysis part of the project. For instance, the only data needed from the Traffic Collisions by Location dataset [17] is the total number of collisions per year, so Pandas will be used to drop all unrelated columns such as 2015_Cyclist. As another example, for the 2015 Tabular Transportation Collison dataset [19], information about small intersections with no red-light cameras will not be needed. In this case, Pandas will be used to drop the rows with this data using the location name.

There are eleven datasets in total:

1. Traffic Collisions by Location 2015 to 2019 [7]

This dataset is a secondary, quantitative dataset from Open Ottawa. It will be downloaded into CSV format and includes a total of 13, 185 rows of data that list the number of traffic collisions in the City of Ottawa by location and year [7]. This is an important dataset for this project because it gives the total number of traffic collisions for each year. This project will be using this information to find out if the number of traffic collisions at an intersection increases or decreases after a red-light camera has been installed.

This dataset was chosen because it is information that is provided directly by the City of Ottawa which means that it should be accurate and unbiased. The dataset also has a map view which means that traffic collision data can be easily found and visualised if needed.

This dataset has a total of 24 variables:

1. Location
2. Geo ID
3. Total_Collisions
4. 2015_Total
5. 2016_Total
6. 2017_Total
7. 2018_Total
8. 2019_Total
9. Total_Cyclists_Collisions
10. 2015_Cyclist
11. 2016_Cyclists
12. 2017_Cyclists
13. 2018_Cyclists
14. 2019_Cyclists
15. Total_Pedestrians
16. 2015_Pedestrians
17. 2016_Pedestrians
18. 2017_Pedestrians
19. 2018_Pedestrians
20. 2019_Pedestrians
21. Xcoord
22. Ycoord
23. Longitude
24. Latitude

Out of all of these, this research project will only be using the following variables:

a. Location
b. 2015_Total
c. 2016_Total
d. 2017_Total
e. 2018_Total
f. 2019_Total

2. Red Light Camera Violations 2015-2019

- Red Light Camera Violations 2015 [6]
- Red Light Camera Violations 2016 [15]
- Red Light Camera Violations 2017 [16]
- Red Light Camera Violations 2018 [17]
- Red Light Camera Violations 2019 [18]

These are secondary, quantitative datasets from Open Ottawa. They will be downloaded into CSV format and include 55 rows each, which correspond to the 55 red-light cameras that had been installed by the year 2019 [18]. These datasets list the number of red-light camera violations per month at each intersection where a red-light camera has been installed in each of the years listed. This project will be taking this data and comparing it to the number of collisions at those intersections to see if the number of red-light camera violations influences the number of collisions.

These datasets were also chosen because they are provided by the City of Ottawa meaning that they are accurate and unbiased [6].

These datasets have a total of 21 variables each:

– Intersection
– Cameral install year
– Latitude
– Longitude
– X
– Y
– Camera facing
– January
– February
– March
– April
– May

- June
- July
- August
- September
- October
- November
- December
- Total violations
- Highest monthly total

Of which this project will be using the following:

- Intersection
- Cameral install year
- Total violations
- Highest monthly total

3. Tabular Transportation Collison Data 2015- 2019
    a. 2015 Tabular Transportation Collision Data [19]
    b. 2016 Tabular Transportation Collision Data [20]
    c. 2017 Tabular Transportation Collision Data [21]
    d. 2018 Tabular Transportation Collision Data [22]
    e. 2019 Tabular Transportation Collision Data [23]

These datasets are secondary, quantitative datasets from Open Ottawa. They will be downloaded into CSV format. The dataset for 2015 includes a total of 15,077 rows [19], the dataset for 2016 includes a total of 14,028 rows [20], the dataset for 2017 includes a total of 14,398 rows [21], the dataset for 2018 includes a total of 14,529 rows [22], and the dataset for 2019 includes a total of 16,399 rows [23].

These datasets are important because they contain specific information that is important to this project. Along with containing information such as the date, time, and location of the collision, these datasets also include the classification of the collision (whether it was fatal or non-fatal), the road conditions and environment at the time of the collision (for instance if the road was icy and it was snowy at the time), as well as the impact type (rear-end collision or right-angle collision) [19]. This data is important to this project because it will help to show what happens when a red-light camera is installed at an intersection. For instance, this data can be used to find out if the number of fatal collisions decrease or if the number of rear-end collisions increase.

These datasets were chosen because it is information that is provided directly by the City of Ottawa which means that it has been validated and should be very accurate [19].

These datasets have 28 variables in total:

1. Anom_ID
2. Accident_Dat
3. Accident_Time
4. Location
5. Geo_ID
6. Accident_Location
7. Classification_of_Accident
8. Initial_Impact_Type
9. Environment_Condition
10. Light
11. Road_Surface_Condition
12. Traffic_Control
13. Traffic_Control_Condition
14. No__of_Vehicles,
15. No__of_Bicycles
16. No__of_Motorcycles
17. No__of_Pedestrians
18. Max_Injury
19. No__of_Injuries
20. No__of_Minimal
21. No__of_Minor
22. No__of_Major
23. No__of_Fatal
24. X
25. Y
26. Latitude
27. Longitude
28. ObjectId

Out of all of these, this research project will only be using the following variables:

- Accident_Date
- Accident_Time
- Location

- Accident_Location
- Classification_of_Accident
- Initial_Impact_Type
- Environment_Condition
- Light
- Road_Surface_Condition
- Traffic_Control
- Traffic_Control_Condition

VI. Detailed data analysis

The objective of this project is to analyze data pertaining to red-light cameras in the city of Ottawa in order to answer the following questions:

- Does the total number of fatal crashes at intersections with red-light cameras decrease in comparison to intersections without red-light cameras?
- Does the number of crashes at an intersection decrease once a red-light camera has been installed?
- Does the number of crashes at an intersection with a red-light camera change over time as drivers become habituated to the presence of the red-light camera?

According to the city of Ottawa's website, the current number of red-light cameras in Ottawa is 75 [4]. Since the datasets being used in this research project are from 2015 to 2019, a decision was made to only look at intersections that had red-light cameras installed in 2017 in order to have enough data before and after the installation (2 years before and 2 years after).

Therefore, the following 13 intersections will be the only intersections with red-light cameras used in this study:

- Hawthorne Road @ Leitrim Road
- Tenth Line Road @ Vanguard Drive
- Heron Road 115 @ W of Bank Street/Canadian Tire SC
- Walkley Road @ Glenhaven Private
- Innes Road @ Orleans Boulevard
- Cedarview Road @ Fallowfield Road
- Prince of Wales Drive @ Meadowlands Drive/Hog's Back
- Aviation Parkway @ Montreal Road
- Bronson Avenue @ Powell Avenue
- Gladstone Avenue @ Rochester Street
- Coldrey Avenue @ Kirkwood Avenue
- Bank Street @ Riverside Drive South
- Catherine Street @ Kent Street

A. Correlation between red-light camera violations and number of traffic collisions

One of the main objectives of this project is to determine if the presence of a red-light camera increases the overall safety of an intersection. To do this, this project tried to find out if there is a correlation between the total number of red-light camera traffic violations and the total number of traffic collisions at an intersection with a red-light camera per year. If the two elements have a negative or positive relationship, further analysis can be done with red-light traffic violation data to help determine the overall safety effects of red-light cameras in Ottawa.

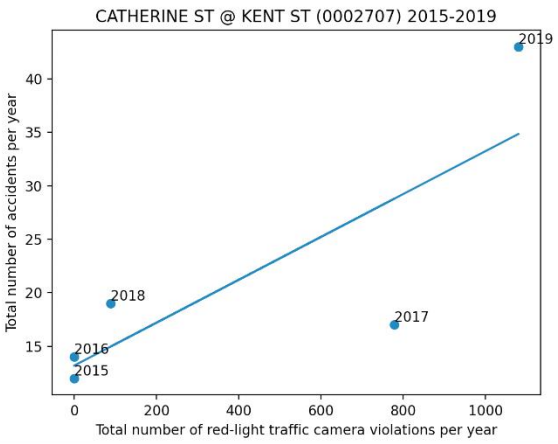
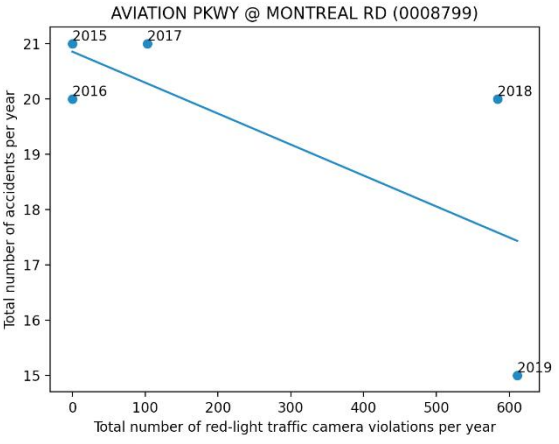
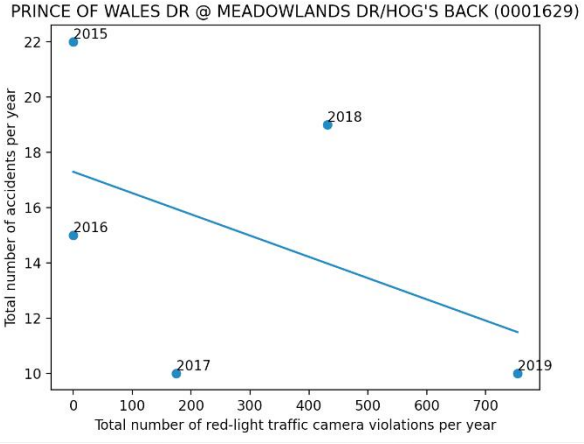
Figures 1.1-1.13 in Table 1 below show a linear regression model for each of the 13 intersections with red-light cameras studied in this research project. The data was taken from the five Red Light Camera Violations tables (from 2015-2019) and the Traffic Collisions by Location 2015 to 2019 table using Python. Then, using the matplotlib library, linear regression models were created for each of the 13 intersections.

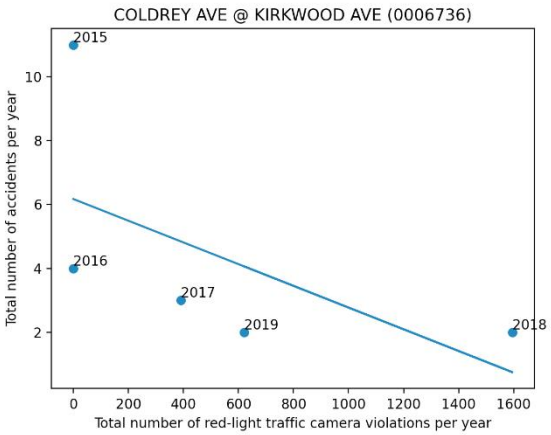
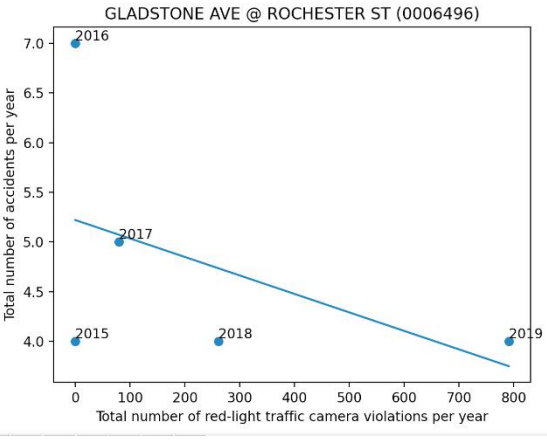
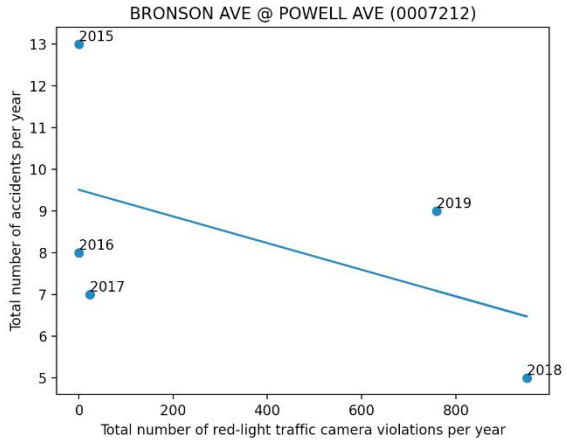
As can be seen from the figures below, there are 6 figures that seem to have an upward trend and 7 that seem to have a downward trend. For the most part, it looks like the total number of traffic violations increases per year after the red-light camera is installed at an intersection.

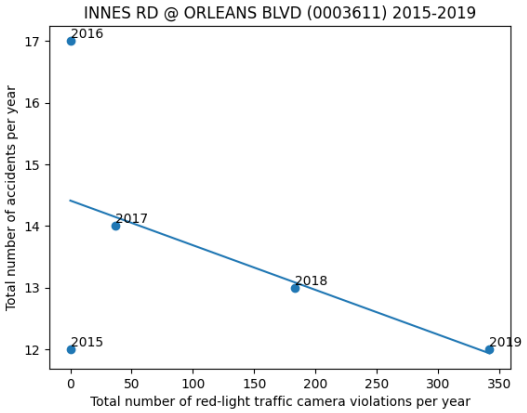
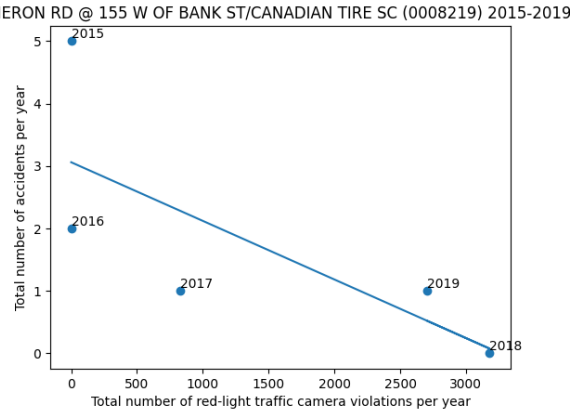
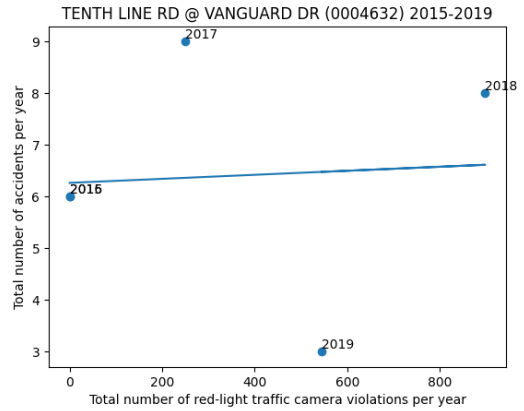
Unfortunately, the linear regression models do not seem to show a relationship between the number of red-light traffic camera violations per year and the total number of accidents per year. This can be verified by looking at the r values for each model. r is the coefficient of relationship; its value determines the

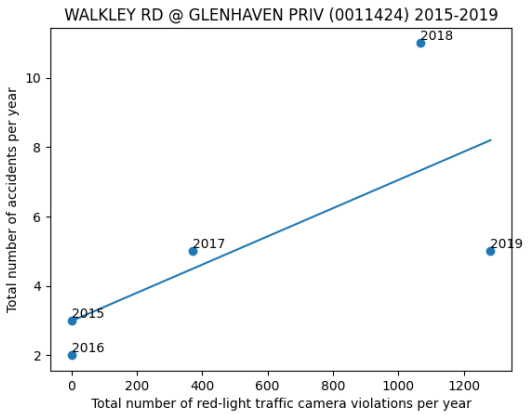
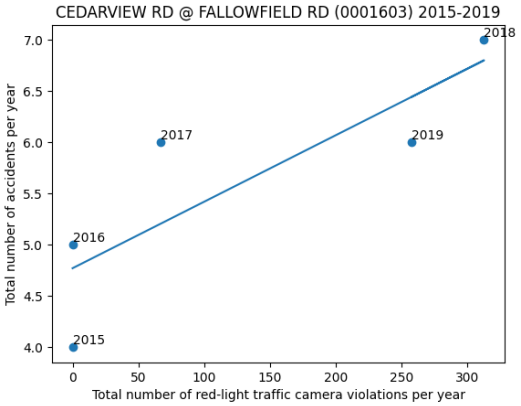
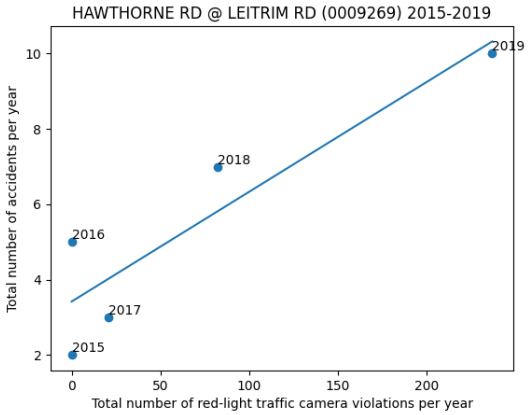
relationship between the values on the x-axis and the values on the y-axis [24]. The closer r is to 1 or -1, the closer the values are related (either negatively or positively). The majority of the r values for the regression models below are closer to 0 than 1 or –1, meaning that the two elements are not correlated.

TABLE I
COMPARISON OF TOTAL NUMBER OF ACCIDENTS AND RED-LIGHT CAMERA VIOLATIONS

Catherine Street @ Kent Street	r = 0.8043889628430231	 Fig. 1.1
Aviation Parkway @ Montreal Road	r = -0.6949754449447139	 Fig. 1.2
Prince of Wales Drive @ Meadowlands Drive/Hog's Back	r= -0.462608219349858	 Fig. 1.3

Coldrey Avenue @ Kirkwood Avenue	r = -0.5904251322998221	 Fig. 1.4
Gladstone Avenue @ Rochester Street	r = -0.4751866617040312	 Fig. 1.5
Bronson Avenue @ Powell Avenue	r = -0.504821013162581	 Fig. 1.6

Innes Road @ Orleans Boulevard	r = -0.52104	 Fig. 1.7
Heron Road 115 @ W of Bank Street/Canadian Tire SC	r = -0.73643	 Fig. 1.8
Tenth Line Road @ Vanguard Drive	r = 0.517791	 Fig. 1.9

Walkley Road @ Glenhaven Private	r = 0.699192	 Fig. 1.10
Cedarview Road @ Fallowfield Road	r = 0.841811	 Fig. 1.11
Hawthorne Road @ Leitrim Road	r = 0.9097449432296763	 Fig. 1.12

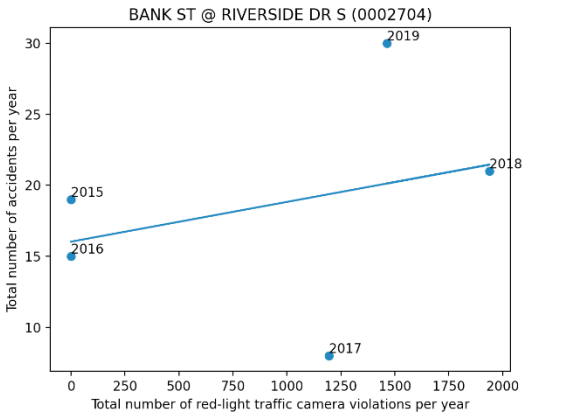
Bank Street @ Riverside Drive South	r = 0.3047853720997983	

Fig. 1.13

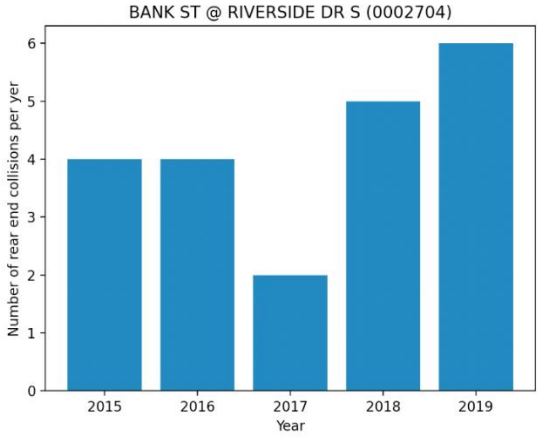
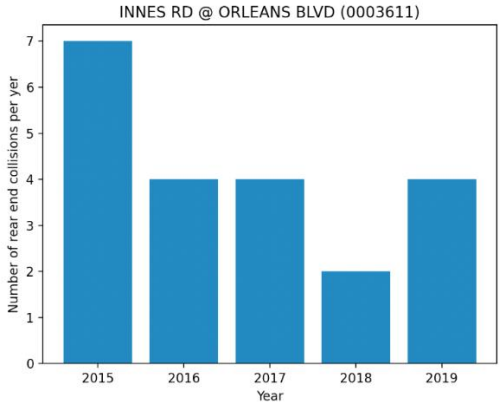
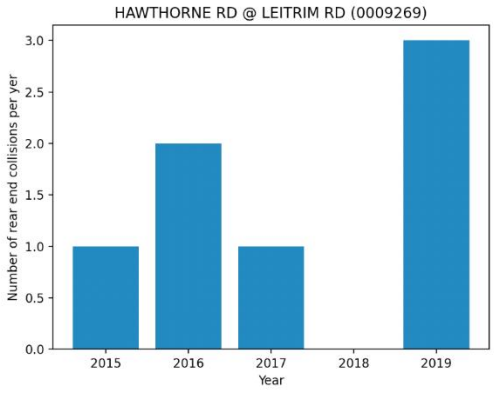
B. Analysis of the number of rear end and angle collisions

One of the objectives of this research project is to find out if red-light cameras increase the safety of an intersection. To do this, data about the number of rear-end and angle collisions for each of the 13 intersections with red-light cameras were taken from the 5 Tabular Transportation Collison Data tables (2015-2019) using Python. The data was then pared down to exclude external factors that may have influenced or caused the accident. To do this, Python was used to drop any rows where the light conditions were not daylight, the road surface conditions were not dry, the environment conditions were not clear, and the traffic control conditions were not functioning.

Many of the related studies reported an increased chance of rear-end crashes at intersections with red-light cameras, as well as a decreased chance of angle or right-/left-crashes [8][9][10][11][13], which makes it an area that is worth looking into, as it may help to determine if anything should be done to prevent these kinds of collisions at red-light camera intersections.

Figures 2.1-2.5 represent the number of rear-end collisions from 2015 to 2019 for the red-light camera intersections in Ottawa. Unfortunately, excluding external factors from the data sets meant that many of the 13 intersections did not have enough data to create a graph. Although it seems like the number of rear-end collisions increases after the red-light camera is installed the data is mostly inconclusive due to the small data set and the small number of graphs that could be created. The data for the angle crashes is also inconclusive for the same reasons.

TABLE II
COMPARISON OF NUMBER OF ANGLE COLLISIONS

Bank Street @ Riverside Drive South	 Fig 2.1
Innes Road @ Orleans Boulevard	 Fig 2.2
Hawthorne Road @ Leitrim Road	 Fig 2.3

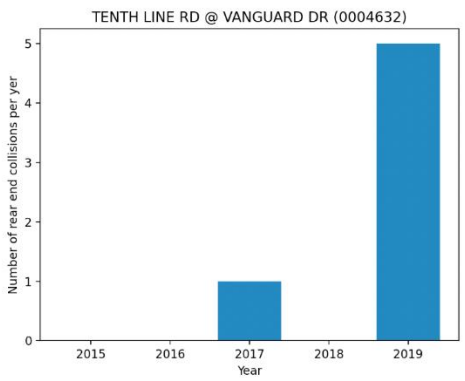
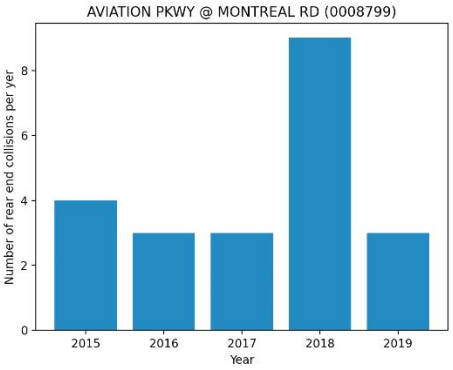
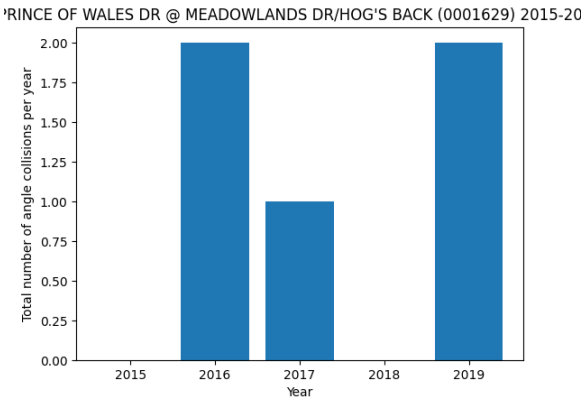
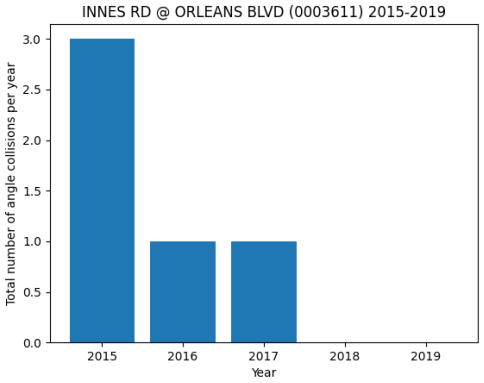
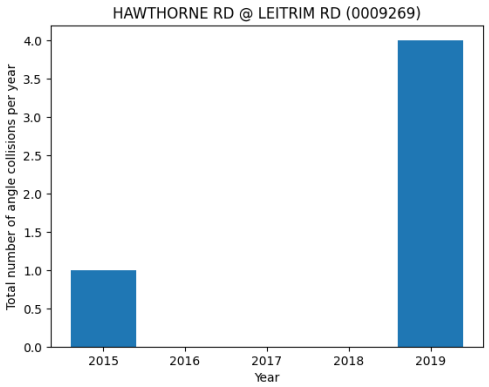
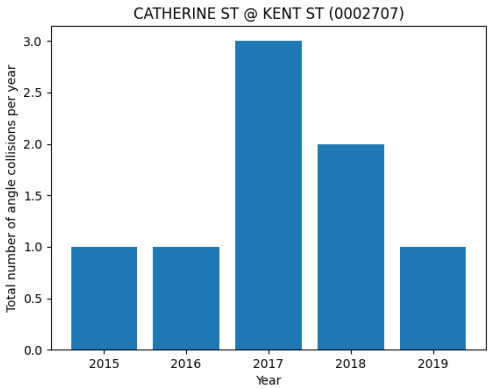
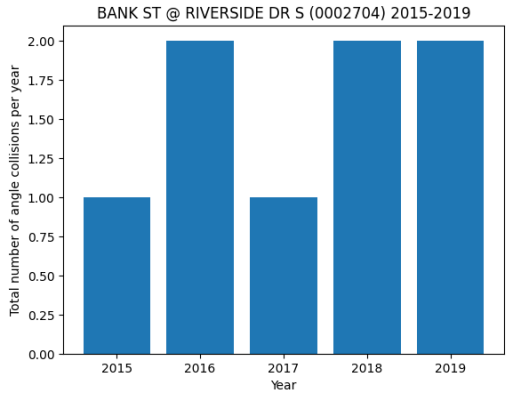
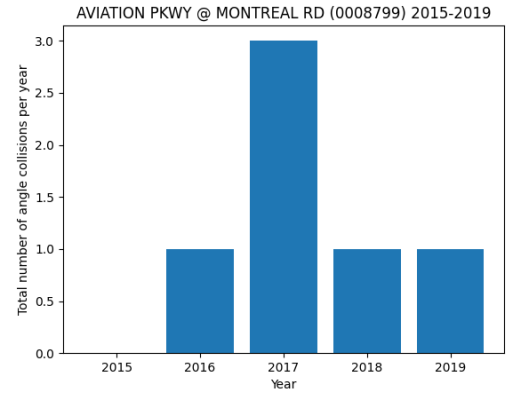
Tenth Line Road @ Vanguard Drive	 Fig 2.4
Aviation Parkway @ Montreal Road	 Fig 2.5

TABLE III
COMPARISON OF NUMBER OF ANGLE COLLISIONS

Prince of Wales Drive @ Meadowlands Drive/Hog's back	 Fig 2.6

Innes Road @ Orleans Boulevard	 Fig 2.7
Hawthorne Road @ Leitrim Road	 Fig 2.8
Catherine Street @ Kent Street	 Fig 2.9

Bank Street @ Riverside Drive South	 Fig 2.10
Aviation Parkway @ Montreal Road	 Fig 2.11

C. Analysis of two similar intersections

The objective of installing a red-light camera at an intersection is to reduce the number of traffic violations and the number of vehicle accidents.[4] In comparing To determine whether the total number of accidents at an intersection decreased with the installation of a red-light camera compared to a similar intersection without a red-light camera, two intersections of similar size and traffic volume were compared based on the total number of accidents per year.

This data was taken from the Traffic Collisions by Location 2015 to 2019 dataset. The intersections selected are Baseline Rd @ Fisher Ave and Prince of Wales Dr @ Meadowlands Dr/Hog's Back. The red-light camera was installed at the latter intersection in 2017.

It was observed that although Prince of Wales Dr @ Meadowlands Dr/Hog's Back had a higher accident rate than Baseline Rd @ Fisher Ave in 2015 and 2016, the two intersections had a similar rate of decrease in the number of accidents across the two years. The number of accidents at Prince of Wales Dr @ Meadowlands Dr/Hog's Back decreases about 30% in 2017, likely due to the installation of the red-light camera, while the number remains the same as the year before at Baseline Rd @ Fisher Ave. In 2018, the number of accidents at Prince of Wales Dr @ Meadowlands Dr/Hog's Back doubled from 2017 for an unknown reason. However, since the number of accidents at Baseline Rd @ Fisher Ave also increases that year, it is possible that there was just an increase in traffic volume in the area. The number of accidents at Prince of Wales Dr @ Meadowlands Dr/Hog's Back does see a 50% decrease in 2019, while Baseline Rd @ Fisher Ave increased at a similar rate as the year before.

Therefore, there does seem to be an effect on the number of accidents in an intersection after the installation of a red-light camera compared to a similar intersection without a red-light camera. There is a decrease in the number of accidents after the installation of the red-light camera however, due to the strange spike in accidents in 2018, it may be possible to look at this across a larger number and variety of intersections for a more conclusive result.

It may also be of note that there were many more read-end collisions at Prince of Wales Dr @ Meadowlands Dr/Hog's Back compared to Baseline Rd @ Fisher Ave, however no definitive conclusions can be drawn from this due to the lack of a broader and more in-depth analysis.

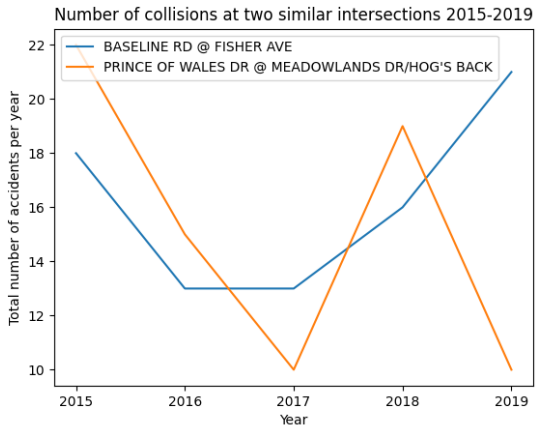


Fig 3.1

VII. Conclusion

The results of this study are inconclusive. No correlation was found between the number of red-light camera violations and the number of accidents at an intersection. It was observed that the number of accidents in an intersection could remain low while having a very high red-light camera violation rate, along with intersections were high. Therefore, it can be said that there is a limited effect on the safety of the intersection, which is the main purpose of installing the red-light camera.

Furthermore, this study was unable to conclude whether a red-light camera affects the number of rear-end, angle, and left-/right-turn collisions at an intersection before, directly after, and for a longer period of time after the installation of the red-light camera. This was in part due to the fact that the data being analyzed was limited due to excluding external factors that could have influenced or caused the accident such as the weather. Therefore, it may be possible to reach a more conclusive result with a larger sample size or by not excluding external factors.

Additionally, in comparing two similar intersections, one with a red-light camera and one without, it is possible to determine that the installation of a red-light camera may have an effect on the total number of collisions in that intersection compared to a similar intersection that does not have a red-light camera. Because this study did not look into this subject in depth, it would be possible to reach a more conclusive result with a broader sample size and a more focused analysis.

These results are relevant in that, although the number of accidents in an intersection did not correlate with the number of red-light camera violations, and there was no effect on the chances of different types of collisions, there is a possible correlation between the existence of the red-light camera in reducing the total number of accidents.

In conclusion, the results of this study are inconclusive and are not useful in determining the safety effects of installing red-light cameras at intersections.

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