Attachment 1

City of Greater Sudbury

Needs and Justification for Red Light Camera Program

Contract ISD15-10

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Date: June 01, 2018

Project #: 60558166

Quality information

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Revision History

Revision	Revision date	Details	Name	Position
00	04/30/2018	Draft for Client Review	Keir Thomas, P.Eng.	Project Manager
01	05/24/2018	Client Comments Addressed	Haider Talib, EIT.	Transportation Engineering Intern
02	06/01/2018	Client Comments Addressed	Haider Talib, EIT.	Transportation Engineering Intern

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AECOM: 2015-04-13

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1. Introduction

1.1 Background

Traffic signals and other traffic control devices are generally installed in order to reduce the number of "conflicts" at intersections. Reducing conflicts, between two or more vehicles and between vehicles and pedestrians, can improve safety and operation of the intersection by separating and controlling the movements of competing traffic and pedestrian movements. However, some motorists intentionally choose to disobey traffic signals and, in doing so, increase the risk of collisions at intersections. Of particular concern at signalized intersections is red-light violation, or "running the red-light", which increases the potential for right-angle collisions. Right-angle collisions in particular can result in more severe damage to vehicles involved, and are more likely to result in injuries to vehicle occupants in comparison to other types of collision impacts, such as rear-end collisions.

There is currently no consistent approach to resolve red-light running issues. There have been safety programs created that include a wider range of engineering, educational, and enforcement measures that are either used individually or in combination in an attempt to reduce or stop red-light running occurrences. From a general engineering perspective, coordinated signal timing plans and improved visibility of traffic signal displays are the two common red-light running treatments in North America. Over the past three decades, many jurisdictions in North America, including several municipalities in Ontario, have also deployed Red-Light Cameras (RLCs) to automate enforcement as a means of reducing the number of red-light running incidents.

An RLC program was initiated in Ontario as a pilot project in November 2000. The six Ontario municipalities who first started using RLCs were City of Toronto, City of Ottawa, City of Hamilton, as well as the Regional Municipalities of Waterloo, Halton, and Peel. A study undertaken in 2003 by one of the AECOM's legacy companies (i.e., Synectics Transportation Consultants) showed the benefits of the RLC program[1] and subsequently, the program received permanent provincial endorsement in 2004. The Regional Municipality of York and City of London have since also joined the RLC program.

At RLC-equipped intersections, an RLC is installed upstream of the intersection, most often on one approach, facing towards the intersection. The RLC takes photographs of the rear of the red-light running vehicles before and after a vehicle crosses the stop bar while the red signal indication is displayed, from which the license plate can then be read and a ticket issued.

Previous studies have shown that on average RLCs reduce right-angle collisions at signalized intersections but they have also been reported to result in an increase of rear-end collisions, at least in the short term. Although frequency of rear-end collisions are typically higher than right-angle collisions at signalized intersections, right-angle collisions tend to be more severe; i.e., more likely to result in injuries to vehicle occupants in comparison to rear-end collisions. Hence, assessment of needs and justification as well as selection of appropriate intersections for RLC installations are two primary, yet key decisions to success of the RLC program; i.e., that the installation of RLCs would lead to an overall reduction in the severity of collisions.

[1] Synectics Transportation Consultants, Evaluation of Red Light Camera Enforcement Pilot Project, Final Technical Report, December 2003.

1.2 Study Objectives

In line with the City of Greater Sudbury's goal to provide safe, efficient, and environmentally-sustainable transportation services, the City has initiated a study and retained AECOM to determine the needs and justification to start a City-wide RLC program and to identify the intersections which would benefit the most from installation of RLCs.

1.3 Study Area

City of Greater Sudbury is the largest city in Ontario by land area, and the largest city in Northern Ontario by population of about 161,000 residents as per the Canada 2016 Census.[2] The population reside in an urban core and many smaller communities that are scattered around the urban core such as Valley East, Nickel Centre, etc. Figure 1 shows the geographical distribution of all signalized intersections in the city of Greater Sudbury.

[2] www.greatersudbury.ca

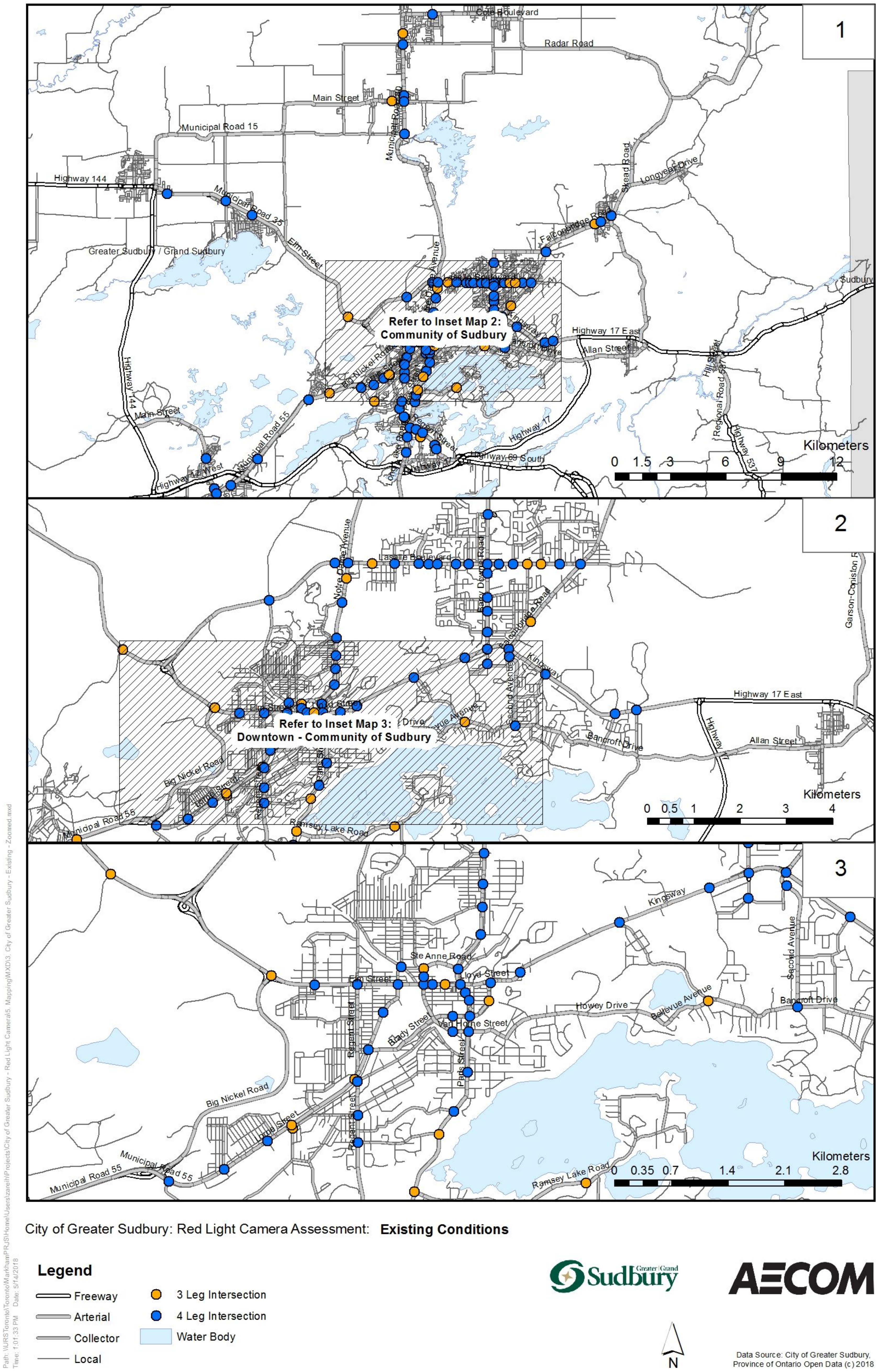

Figure 1: Signalized Intersections in the Greater Sudbury Area

2. Literature Review on Safety Benefits of RLCs

Since the 1970s, numerous jurisdictions in Europe, Australia, and North America have been using RLCs with the aim of reducing red-light violations and the resulting collisions. A number of studies have been conducted by researchers to evaluate safety benefits of RLCs *(1 – 9)*. The majority of the past studies' findings appear to support a conclusion that RLCs reduce right-angle collisions and could increase rear-end collisions whereas there is no evidence that RLC installation affects other collision impact types[3]. Hence, to assess the needs and justification for installation of RLCs in the City of Greater Sudbury and to identify intersections that would benefit the most from the RLC installations, the effect of RLCs on right-angle and rear-end collision frequencies were estimated.

Accurately quantifying the safety effects of an RLC program has generally been a challenging task. This has been evidenced by relatively considerable variations in study findings on magnitude of the safety benefits of the RLC programs. However, for the purpose of the City of Greater Sudbury's Study and based on findings of the most reliable multi-jurisdictional safety evaluation of RLCs[4], it is assumed that RLCs reduce right-angle collisions at signalized intersections by 25% and initially increase rear-end collisions by 15%.

In addition, the previous studies have shown that the safety benefits of RLCs usually spill-over from the RLC-equipped intersections (i.e., "treated" intersections) to the adjacent signalized intersections that do not have RLCs (i.e., "untreated" intersections). In other words, RLCs not only result in a fewer number of red-light running / violations at the treated intersections but they also modify driving behaviour at the untreated intersections because of the jurisdiction-wide publicity of an RLC program and the general public's lack of knowledge of where RLCs are installed. However, the literature review showed that the spill-over effect is typically a longer-term result of the RLC program and its order of magnitude has not been thoroughly examined / precisely quantified in the literature. Therefore, the spill-over effects was not directly accounted for in assessing the needs and justification for installation of RLCs in the City of Greater Sudbury.

Furthermore, the available literature shows that failure to account for the "regression-to-the-mean" (RTM) phenomenon could result in overestimation of RLCs safety benefits. RTM occurs where intersections are selected for RLC installations based on their high number or rate of right-angle collisions and low number of rear-end collisions which would have reduced and increased, respectively, whether or not an intervention was made.[5] Hence, for the purpose of the City of Greater Sudbury's Study and as further explained in <u>Section 4</u>, the Empirical Bayes (EB)[6] approach was adopted to control for the RTM phenomenon and to estimate the expected number of right-angle and rear-end collisions.

[3] American Association of State Highway and Transportation Officials (AASHTO), Highway Safety Manual, 2010
[4] Persaud, B., Council, F. M., Lyon, C., Eccles, K., and Griffith, M., "A Multi-Jurisdictional Safety Evaluation of Red Light Cameras.", Transportation Research Record 1922, (2005) pp. 29-37
[5] Solomon H., Izadpanah, P., Brady, M, and A. Hadayeghi, *So You're Considering a Red Light Camera Program? Lessons and Insights from over a Decade of Camera Operation in South and Central Ontario*, paper prepared for presentation at the Road Safety Policy Development – Past, Present, Future session of the 2014 Conference of the Transportation Association of Canada, Montreal, Quebec, Source: http://conf.tac-atc.ca/english/annualconference/tac2014/s-6/solomon.pdf
[6] The Empirical Bayes (EB) methodology adopted in this report is an industry standard, it is referred in the 2010 Highway Safety Manual.

3. Data Collection, Verification, and Processing

3.1 Data Collection

The City of Greater Sudbury provided the AECOM project team with the historical data on the motor vehicle collisions that were reported to occur at the City's signalized intersections over a period of 5 years from January 1, 2012 to December 31, 2016. The City also provided the available annual average daily traffic (AADT) volumes for both major and minor intersecting roadways at the signalized intersections over the same period of time. Each of these two datasets is discussed in the following sub-sections with more details.

The additional data provided by the City include traffic signal installation year, description of modifications (if any) made to intersection geometry and traffic control devices at the signalized intersections within the study period, among others.

3.1.1 Traffic Volume Data

For each intersection, the traffic volume database contains a unique intersection ID (i.e., a six-digit number called GEOID), description of intersecting roadways, number of legs, AADT volumes on all approaches, entering AADT volumes from both major and minor intersecting roadways, and year in which AADT volumes were collected. Note that for each intersection, the City provided AADT volumes only for one year out of five years between 2012 and 2016; i.e., there is only one set of AADT volumes per intersection. The database also contains information about the implementation year and type of geometric improvements (if any) made to the City's signalized intersections over the five-year study period.

3.1.2 Collision Data

The City also provided the motor vehicle collision data for the five-year study period. The database included all of the collisions that were coded as either "at intersection" or "intersection-related". The collision data were made available as an Excel file. For each collision record, the collision database contains a unique collision ID, date and time of occurrence (including year, month, day, and time), GEOID and description of the intersection at which or in its vicinity the collision has occurred, classification or severity (i.e., fatal injury, non-fatal injury, property damage only, non-reportable, and other / unknown), initial impact type (e.g., angle, rear-end, sideswipe, turning movement, single motor vehicle, etc.), environment condition (i.e., weather condition), light condition (e.g., daylight, dark, dawn, etc.), driver condition (e.g., driving properly, following too close, disobeyed traffic control, etc.), road surface condition (e.g., dry, wet, slush, etc.), driver action(s), initial direction(s) of travel, direction of travel in which at-fault driver was travelling (if known), and the traffic signal condition (e.g., functioning, obscured, etc.).

3.1.3 Other Data

As discussed further in Section 4.3, the City also provided the AECOM project team with the signal timing plans and design drawings of the City's candidate intersections that were identified for the RLC installations.

3.2 Consistency and Completeness Checks and Modifications of Data

In general, accuracy of analysis findings is highly dependent on extent and quality of data inputs. Based on a preliminary assessment, the available data (i.e., total number of intersections and collisions as well as number of their available data fields) was found sufficient to complete a statistically valid collision assessment to achieve the study objectives. However, as a matter of due diligence and to confirm and enhance (where needed) quality of the traffic volume and collision data, the City's and AECOM project teams conducted a set of consistency checks and subsequent modifications.

With respect to the collision data and in consultation with the City staff, all of the self-reported collisions were excluded from the database. This was done due to low level of confidence in validity of the "self-reported" collision records. It is worth mentioning that only rear end and right angle collisions data are used in the study since RLCs impact is limited to these two types of collisions. The study team also identified some missing data with respect to the collision classification, initial impact type, and vehicle direction of travel fields. There were also some inconsistencies between the reported initial impact type and the direction of travel of vehicles. For example, for some of the records reported as angle collisions, the reported directions of travel for the two vehicles involved were not perpendicular. Similarly, there were records of rear-end collisions for which it was reported that vehicles were traveling in opposite directions of travel. Subsequently, and with verifications of the identified data fields against the related motor vehicle collision reports (MVCRs) by the City staff, the identified data inconsistencies were corrected and the identified missing information were populated. A portion of the missing information on collision classification and / or initial impact type that cannot be confidently determined was categorized as "other".

With respect to the traffic volume data, the study team focused on identifying the intersections for which the AADT volume field was blank and those with more than one GEOID (i.e., duplicate GEOIDs) data as shown in Table 1. Subsequently, the City staff provided the AADT volumes and verified the correct GEOIDs. In addition, the following two intersections were also excluded from the database because their traffic signals were installed in 2017 because the collision data provided corresponded to the period before installation of the signals:

- Second Avenue and Scarlett Road; and
- Second Avenue and Kenwood Street.

Following the above-noted data modifications, the collision database was linked to the traffic volume database using the GEOID field to form a master database. Finally, the master database was divided into two datasets; one for the three-legged intersections and one for the four-legged intersections.

Table 1: List of the Intersections with Missing AADT or Duplicate GEOIDs

Intersection	Type of Issue
Brady Street and Lloyd Street	Duplicate GEOID
Municipal Road 55 and Magill Street	Duplicate GEOID
Lorne Street and Rowat Street	Duplicate GEOID
Regent Street and Walford Road	Duplicate GEOID
Falconbridge Road and Penman Avenue	Missing AADT Volumes
Caswell Drive and Regent Street	Missing AADT Volumes

3.3 Overview of the City's Collision Data

As stated in Section 2 of the Report, based on the most reliable past research studies, RLCs on average reduce right-angle collisions by 25% and increase rear-end collisions by 15% and there is no evidence that RLC installation affects other collision impact types. Hence, for the purpose of this study, right-angle and rear-end collisions were considered as target collisions.

Excluding the two noted intersections on Second Avenue that were signalized in 2017, there are 94 four-legged and 20 three-legged signalized intersections within the City boundaries. There were 464 right-angle and 1622 rear-end collisions reported to occur at these signalized intersections over the five-year study period. Figure 2 shows frequencies and proportion of injury and property-damage-only (PDO) collisions for the right-angle collisions. Figure 3 shows the same information for the rear-end collisions. Intuitively and consistent with the past studies, right-angle collisions are shown to result in more severe collisions than rear-end collisions. It is essential to note that there is no record of fatal right-angle and rear-end collisions at the City's signalized intersections over the five-year study period.

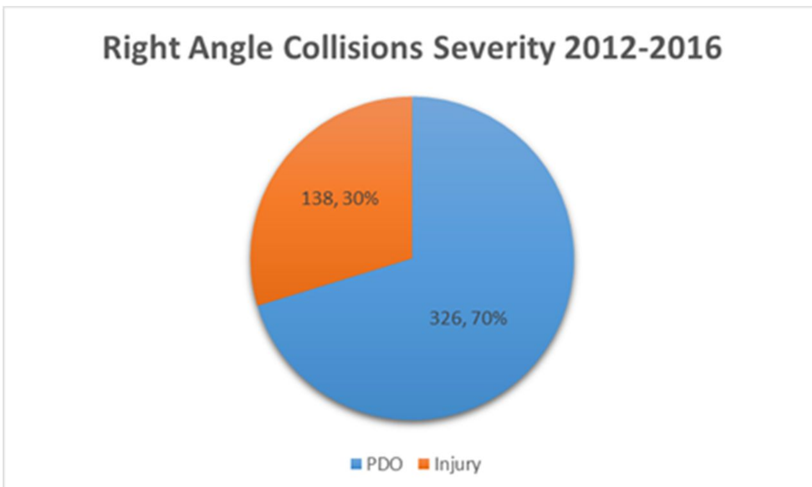

Figure 2: Frequency and Proportion of Right-Angle Collisions by Severity

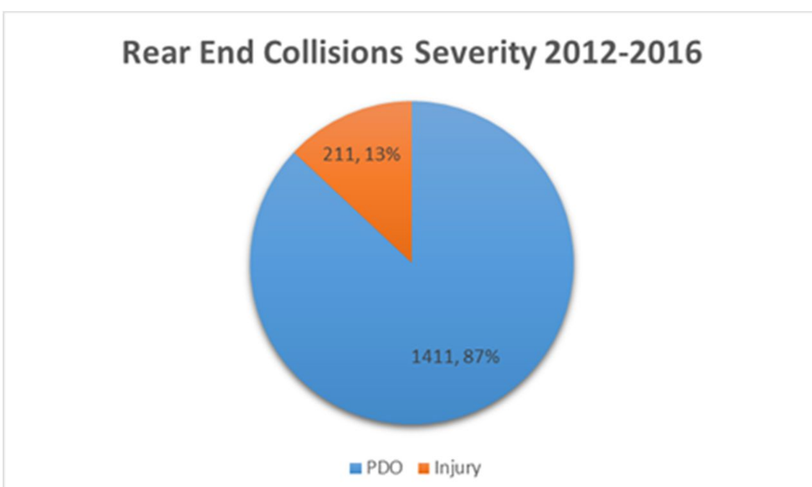

Figure 3: Frequency and Proportion of Rear-End Collisions by Severity

4. Study Methodology and Findings

This Section is intended to present the methodology adopted to achieve the study objectives stated in Section 1.2. The study was broken down into the following four tasks:

- Develop safety performance functions (SPFs) separately for the three-legged and four-legged signalized intersections;
- Identify candidate signalized intersections for installation of RLCs;
- Undertake field investigations and engineering assessment of the candidate signalized intersections; and
- Identify signalized intersections that would benefit the most from installation of RLCs.

4.1 Develop Safety Performance Functions for the Signalized Intersections

As stated in Section 2 and for the purpose of this study, the EB method was adopted as a superior method to estimate the expected frequencies of target collisions (i.e., right-angle and rear-end collisions) at all of the City's signalized intersections in the status quo (i.e., without RLCs). The EB method aims to smooth out typical random fluctuations in any specific intersection's collision history and estimate the expected collision frequency $E\{m\}$ for both right-angle and rear-end collisions at the intersection. For either of the two target collisions, the expected collision frequency is calculated as a weighted average of the historical (observed) collision frequency (x) and predicted collision frequency $E(Y)$ which is in turn obtained based on historical collision frequencies of numerous other intersections with similar characteristics in terms of entering AADT volumes, number of legs, traffic control devices, etc. The following formula mathematically expresses the EB method.

$$E\{m\} = w * E(Y) + (1 - w) * x$$

To predict the collision frequencies $E(Y)$ of the target collisions and to calculate the noted weight (w) in the above-noted formula, safety performance functions (SPFs), also known as collision prediction models, are needed. Hence, as part of this study and using the most recent five-year historical collision data and the related entering AADT volumes at three-legged and four-legged signalized intersections, SPFs were developed to predict the number of right-angle and rear-end collisions at those signalized intersections. As illustrated in Figure 4, separate SPFs were developed for four-legged and three-legged intersections.

For each of the two intersection categories, SPFs were developed separately for right-angle and rear-end collisions.

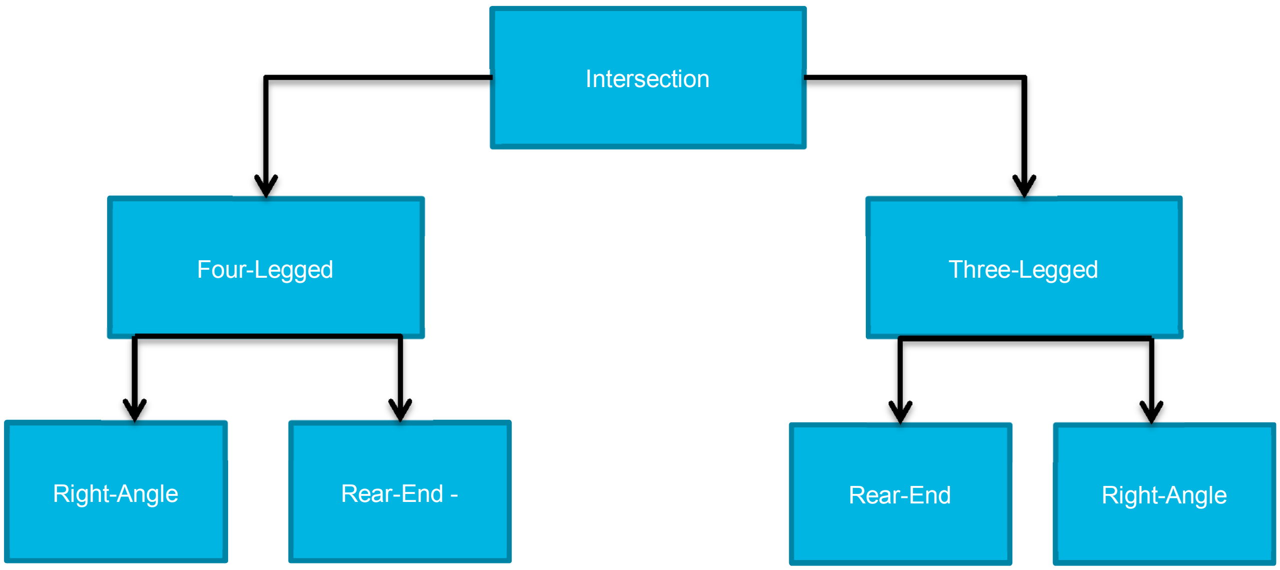

Figure 4: Intersection-Collision Impact Type Categories for SPF Development

Table 2 and Table 3 present SPFs to predict number of right-angle and rear-end collisions for both signalized four-legged and three-legged intersections respectively.

Table 2: SPFs for Signalized Four-Legged Intersections

Collision Impact Type	Equation	Intercept (α)	β_1	k
Angle	$E(Y) = \alpha * (MajorAADT + MinorAADT)^{\beta_1}$	-12.72	1.29	0.74
Rear-End		-21.33	2.23	0.61

Table 3: SPFs for Signalized Three-Legged Intersections

Collision Impact Type	Equation	Intercept (α)	β_1	β_2	k	C_1	C_2
Angle	$E(Y) = \alpha * (MajorAADT)^{\beta_1} * (Minor\ AADT)^{\beta_2}$	-12.13	1.11	0.26	0.33	0.10	1.40
Rear-End		-12.13	1.11	0.26	0.33	0.53	1.91

Where, α, β_1, β_2 are the model parameters.

C_1, C_2 are the calibration factors that were calculated based on the AASHTO Highway Safety Manual (HSM) guidelines and subsequently, used in development of SPFs for the City's three-legged signalized intersections.

k is the over-dispersion parameter used in calculating the weight (w).

4.2 Identify Candidate Intersections for RLCs

4.2.1 Potential for Safety Change as a Result of RLC Installations

In order to determine if, at what locations, and to what extent the RLC installations would result in net potential safety benefits to the City of Greater Sudbury, the AECOM project team estimated potential for safety change (PSC) at all signalized intersections. The PSC is defined as the difference between the expected number of the target collisions (i.e., right-angle and rear-end collisions) before and after RLC installations at that intersection and it is described in terms of equivalent PDO (EPDO) collisions. The EPDO is used as unit of measurement because it allows for assigning a greater weight to right-angle collisions due to their more severe nature (thus, greater societal costs) than rear-end collisions in calculation of the PSC for each intersection.

The first step in estimating the PSC for an intersection is to evaluate the expected number of target collisions with no RLC in place. As described in Sub-section 4.1, the expected number of target collisions at the intersection in the absence of RLCs is estimated using the EB method.

The second step is to project the expected number of target collisions at the intersection if an RLC is installed. The expected number of target collisions with an RLC is estimated by multiplying the applicable collision modification factors (CMFs) to the expected number of collisions before the RLC installation. As stated in Section 2, the CMFs for the target collisions are:

- 0.75 for right-angle collisions; this represents 25% reduction in right-angle collisions following RLC installation, and
- 1.15 for rear-end collisions; this represents a 15% increase in rear-end collisions.

Finally, the PSC for an intersection is calculated by subtracting the expected number of collisions if an RLC was in place and the expected number of collisions with no RLC in place at the intersection. A negative PSC represents a potential for safety improvement and a positive PSC represents a potential for safety deterioration.

Table 4 presents the PSC values for each signalized intersections, ranked in descending order of predicted benefit. For example, the intersection of Paris Street and Cedar Street, if equipped with an RLC, is expected to experience a reduction of approximately four fewer EPDO collisions per year. As shown in Table 4, a total of fifty five signalized intersections were identified as those with negative PSC values. In other words, it was determined that fifty five intersections would gain safety benefits from installation of RLCs. This finding satisfies the first objective of this study that there is a justification for installation of RLCs from a road safety standpoint. It is essential to note that out of the original 114 signalized intersections, 20 of the intersections had no record of right-angle collisions within the five-year study period and therefore, were excluded from further analysis. This reduces the total number of signalized intersections that were carried forward for further analysis to 94.

Table 4: Intersection Ranking Based on the PSC Index

Rank	GEO ID	Intersection	PSC index	Intersection type
1	145100	Paris @ Cedar	-4.3420	4-Legged
2	145121	Paris @ Van Horne	-2.0237	4-Legged
3	144278	Lorne @ Douglas	-1.9754	4-Legged
4	144144	Regent @ Beatty	-1.8621	4-Legged
5	145358	Notre Dame @ Cambrian Heights	-1.6133	4-Legged
6	144866	Regent @ Algonquin	-1.5837	4-Legged
7	144062	Municipal road 80 @ Dominion	-1.5570	4-Legged
8	145783	Lasalle @ Montrose	-1.0664	4-Legged
9	145054	Notre Dame @ Elm	-1.0616	4-Legged
10	145259	Notre Dame @ Kathleen	-1.0285	4-Legged
11	144606	Paris @ Walford	-0.9564	4-Legged
12	144738	Elm @ Elgin	-0.9512	4-Legged
13	145220	Municipal road 80 @ Elmview	-0.9046	4-Legged
14	146232	Barry Downe @ Hawthorne	-0.8453	4-Legged
15	144424	Lorne @ Walnut	-0.8104	4-Legged
16	146404	Bancroft @ Second	-0.8086	4-Legged
17	145140	Paris @ Larch	-0.7906	4-Legged
18	143506	Lorne @ Gutcher	-0.7243	4-Legged
19	144286	Long Lake @ St Charles Lake	-0.7242	4-Legged
20	145242	Lasalle @ Crescent Park	-0.6831	4-Legged
21	144171	Regent @ York	-0.6501	4-Legged
22	143280	Lorne @ Kelly Lake	-0.6477	4-Legged
23	146734	Lasalle @ Gary	-0.6414	4-Legged
24	142896	Municipal road 55 @ Magill	-0.5113	4-Legged
25	146233	Barry Downe @ Marcus	-0.4792	4-Legged
26	143636	Main Street @ Marie Avenue	-0.4685	4-Legged
27	147382	Falconbridge @ Church	-0.4627	4-Legged
28	144155	Regent @ Riverside	-0.4602	4-Legged
29	146077	Lasalle @ Roy	-0.3996	4-Legged
30	145040	Notre Dame @ St Anne	-0.3801	4-Legged
31	144641	Paris @ Centennial	-0.3694	4-Legged
32	146228	Barry Downe @ Gemmell	-0.3612	4-Legged
33	145833	Lasalle Blvd. @ Lasalle Court Mall	-0.3602	4-Legged
34	146287	Lasalle Blvd. @ Superstore	-0.3131	4-Legged
35	144121	Regent @ Telstar	-0.3037	4-Legged
36	147073	Falconbridge @ Maley	-0.3018	4-Legged

Rank	GEO ID	Intersection	PSC index	Intersection type
37	146222	Barry Downe @ NSSM	-0.2848	4-Legged
38	147113	Kingsway @ Moonlight	-0.2645	4-Legged
39	142724	Municipal road 55 @ Hillcrest	-0.2593	4-Legged
40	144258	Long Lake @ Countryside	-0.2451	4-Legged
41	143695	Elm Street @ Ethelbert Street	-0.2227	4-Legged
42	143887	Regent @ Bouchard	-0.2150	4-Legged
43	143384	Kelly Lake @ Copper	-0.1970	4-Legged
44	144575	Frood @ College	-0.1966	4-Legged
45	146243	Barry Downe @ Lillian	-0.1957	4-Legged
46	145493	Kingsway @ Cochrane	-0.1775	4-Legged
47	143999	Regent @ Martindale	-0.1636	4-Legged
48	144807	Elm @ Durham	-0.1432	4-Legged
49	142394	Municipal Road 35 @ Elizabeth	-0.1424	4-Legged
50	145143	Paris @ Brady	-0.1355	4-Legged
51	144734	Elgin @ Beech	-0.1156	4-Legged
52	146618	Lasalle @ Lansing	-0.0989	4-Legged
53	144141	Municipal Road 80 @ Valleyview	-0.0362	4-Legged
54	142874	MR 35 @ Marier Street	-0.0343	4-Legged
55	147296	Falconbridge @ Margaret	-0.0072	4-Legged
56	146229	Barry Downe @ Westmount	0.0248	4-Legged
57	146378	Lasalle @ Paquette	0.0356	4-Legged
58	146649	Kingsway @ Third	0.0486	4-Legged
59	144557	Elm @ Lorne	0.0563	4-Legged
60	144639	Regent @ Old Burwash	0.0674	4-Legged
61	145884	Lasalle @ Arthur	0.0947	4-Legged
62	145327	Brady @ Lloyd	0.0957	4-Legged
63	145267	Notre Dame @ King	0.1515	4-Legged
64	147070	Kingsway @ Levesque	0.1602	3-Legged
65	147254	Falconbridge Road @ Penman Avenue	0.1937	3-Legged
66	144193	Regent @ Caswell	0.2081	3-Legged
67	146055	Bancroft @ Bellevue	0.2156	3-Legged
68	144922	Elm @ Lisgar	0.2181	3-Legged
69	142633	Municipal Road 55 @ Black Lake	0.2250	4-Legged
70	144873	Paris @ York	0.2330	3-Legged
71	143574	Lorne @ Martindale	0.2523	4-Legged
72	144107	Lorne @ Regent	0.3095	3-Legged
73	144052	MR 80 @ Jeanne D'Arc Street	0.3193	3-Legged
74	145278	Notre Dame @ Wilma	0.3198	4-Legged

Rank	GEO ID	Intersection	PSC index	Intersection type
75	144269	Lasalle @ Frood	0.3306	4-Legged
76	143517	Elm @ Big Nickel	0.3577	3-Legged
77	145675	Ramsey Lake @ LU	0.4294	3-Legged
78	143240	Elm @ Clarabel	0.4563	3-Legged
79	143181	Municipal Road 55 @ Balsam	0.4624	3-Legged
80	146555	Falconbridge @ Auger	0.5039	4-Legged
81	146525	Lasalle @ Auger	0.6528	3-Legged
82	145598	Lasalle @ somers	0.7086	3-Legged
83	144123	MR 80 @ Main Street	0.8095	4-Legged
84	146916	Lasalle @ Falconbridge	0.8373	4-Legged
85	145995	Lasalle @ Attlee	0.8646	4-Legged
86	145239	Notre Dame @ Leslie	1.0085	4-Legged
87	145674	Lasalle @ Rideau	1.0804	4-Legged
88	144415	Regent @ Long Lake	1.1688	4-Legged
89	145759	Kingsway @ Bancroft[7]	1.1833	4-Legged
90	146221	Lasalle @ Barry Downe	1.2735	4-Legged
91	146239	Kingsway @ Barry Downe	1.2983	4-Legged
92	145417	Lasalle @ Notre Dame	1.6878	4-Legged
93	144673	Paris @ Ramsey Lake	2.1314	3-Legged
94	146342	Kingsway @ Falconbridge	2.5646	4-Legged

4.2.2 Additional Candidate Intersections

Available data were limited in that AADT data were only available for one year at each intersection, as compared with five years of collision data at each intersection. This raised the possibility that intersections existed which could benefit from RLC installation but were excluded from the original top six lists because of the data limitations. Accordingly, AECOM undertook a review of the collision data to identify intersections with high frequency of right-angle collisions that may have been excluded from the top six list, and determine whether there is reason to believe that they might also benefit from RLC installation.

Table 5 shows the eight signalized intersections with the highest number of right-angle collisions over the study period and ranked in a decreasing order. It also shows the estimated PSC values for these intersections and their ranks from Table 4.

[7] Traffic volumes and collision data were received after the submission of the draft report and therefore, were not included in the development of the SPF models for the city's intersections

Table 5: Top Eight Intersections based on Total Number of Right-Angle Collisions between 2012 and 2016

GEOID	Rank	Rank in Table 4	Intersection Description	PSC Value	Total Number of Right-Angle Collisions (2012 - 2016)
145100	1	1	Paris Street and Cedar Street	-4.34	21
144144	2	4	Regent Street and Beatty Street	-1.86	20
144738	3	12	Elm Street and Elgin Street	-0.95	16
146221	4	90	LaSalle Boulevard and Barry Downe Road	1.27	16
145121	5	2	Paris Street and Van Horne Street	-2.02	15
145143	6	50	Paris Street and Brady Street	-0.14	13
144415	7	88	Regent Street and Long Lake Road	1.17	13
144062	8	7	Municipal Road 80 and Dominion Road	-1.56	10

Intersections in tables 4 and 5 were combined. After deleting duplicate entries and locations with positive PSC values, a total of nine candidate sites remained.

Of the remaining nine locations, it was noted that three were in close proximity to one another, namely Paris @ Cedar, Paris @ Brady, and Paris @ Van Horne. Since it is expected that the RLC spill-over effect will benefit intersections near those where an RLC is installed, it was agreed to eliminate two of the three sites from the short-list. Paris @ Cedar was carried forward because it had the greatest potential safety change of all sites in the City.

After the list was modified as per above, a total of seven sites remained. Since all seven sites showed a potential safety improvement from RLC installation and there was no significant reason to select any site over the others, the City issued a change order to increase the number of sites carried forward to office and field investigations from six to seven. The final seven locations are:

- Paris Street and Cedar Street
- Lorne Street and Douglas Street
- Regent Street and Beatty Street
- Notre Dame Avenue and Cambrian Heights Drive
- Regent Street and Algonquin Road
- Elm Street and Elgin Street
- Municipal Road 80 and Dominion Road

4.3 Field Investigations and Engineering Assessment

The objective of RLC installations is to reduce collisions by reducing the number of intentional red-light running incidents. It should be noted, however, that conditions may be present which contribute to unintentional red light running and could, if addressed, provide the intended safety improvement more quickly, efficiently or cost-effectively than installing RLCs. Accordingly, the AECOM project team conducted a set of engineering assessments and field investigations to identify potential factors contributing to unintentional red light running incidents, and other factors which may impact the safety of each of the top seven intersections.

4.3.1 Engineering Assessment

Prior to the field investigation stage, the AECOM project team reviewed the signal timing plans of the seven candidate intersections to confirm adequacy of amber and all-red clearance intervals. Timing plans were compared with the timing guidelines outlined in the Ontario Traffic Manual (OTM) Book 12[8].

The duration of an amber interval is set to provide adequate advance time to an approaching motorist about the forthcoming change from amber to red. In addition, the all-red clearance interval is intended to allow a motorist who has entered the intersection (driven past the stop line) to have enough time to clear the intersection before the start of green interval for the next traffic signal phase. Based on the office review, the duration of clearance intervals were found to be acceptable, with the exception that at some intersections, the current all-red clearance intervals are slightly shorter than the minimum recommended values in the OTM Book 12. However, the slightly shorter all-red clearance intervals are not expected to be a contributing factor behind the observed right-angle and rear-end collisions at the seven candidate intersections; thus, all of the seven candidate intersections were carried forward for the field investigations.

In preparation for the field investigations and based on the available collision data, the AECOM Project team developed a scoring methodology to rank the legs of each intersection in terms of the reported number of collisions for which the at-fault driver was driving on. The at-fault drivers and the intersection leg on which the at-fault driver was travelling were identified based on the available collision data in the direction of travel and driver action columns. For each right-angle or rear-end collision record, the at-fault driver is identified as the one who was reported as “Disobeyed Traffic Control”, “Failed to Yield Right of Way”, “Following Too Closely”, “Improper Turn”, “Lost Control”, etc. It was also taken into account that a right-angle collision is typically more severe than a rear-end collision, and therefore are weighted heavier in the scoring process. In addition, for right-angle collision records that both drivers were reported as “Driving Properly”, both approaches on which the two involved drivers were travelling on was scored equally. Table 5 shows a summary of the scoring process for the seven candidate intersections. For each candidate intersection, the leg with the highest score (highlighted in gray in Table 6) is identified as the critical leg of the intersection.

Table 6: Scoring Results for Ranking Intersections Legs

Intersection Description	Approaches			
	NB	SB	WB	EB
Paris Street and Cedar Street	27	1	32	6
Regent Street and Beatty Street	17	7	6	19
Lorne Street and Douglas Street	-12	1	10	3
Elm Street and Elgin Street	10	17	-3	22
Municipal Road 80 and Dominion Road	-3	5	8	6
Regent Street and Algonquin Road	-9	-18	10	1
Notre Dame Avenue and Cambrian Heights Drive	-16	-3	6	-1

The ranking of the intersection legs was intended to inform the AECOM project team on how to prioritize (if needed) field investigation activities and where to focus the most. The exercise of identifying the critical legs was not intended to choose the intersection leg at which RLC is recommended for installation. The rationale is that in Ontario, the RED LIGHT CAMERA signs (see Figure 5) are posted on all approaches to an intersection which is equipped with RLC; thus, no matter on which leg of the intersection the RLC is installed, the posted RED LIGHT CAMERA signs on all approaches to the intersection are anticipated to change driver behavior on equally on all the approaches.

[8] Ontario Traffic Manual (OTM) Book 12, page 44 - 46

Figure 5: Red Light Camera Sign

4.3.2 Field Investigations

Subsequent to the completion of the office reviews, the seven candidate intersections were visited by two members of the AECOM project team over three days between Tuesday, April 10 and Thursday, April 12, 2018 when road surface was dry and for the most part there was no precipitation.

The primary focus of the field investigations was to identify any potential issue that could lead to right-angle collisions and to confirm adequacy of the available sight distances to primary and auxiliary traffic signal heads and warning signs (e.g., Traffic Signal Ahead warning sign, etc.) on all approaches to the seven candidate intersections. The field crew also assessed the status of pavement markings, possibility of sun glare, sign clutter, potential driver distraction (e.g., digital advertisement sign, etc.), lane continuity, etc.

4.4 Selection of Red Light Camera Sites

Table 7 provides a summary of the field investigations of the seven candidate intersections and the recommendations on where to install RLCs.

Among the seven candidate intersections, the following three were recommended for RLC installations:

- Paris Street and Cedar Street;

- Municipal Road 80 and Dominion Road; and
- Regent Street and Algonquin Road.

Figure 6 shows the geographical distribution of the seven candidate intersections and the three recommended intersections for the RLC installations.

For the other four intersections, a number of potential engineering solutions should be considered for implementation and assessed for effectiveness prior to revisiting them for RLC installations. The noted potential treatments in Table 7 are by no means considered comprehensive and no particular detailed assessment of their potential effectiveness has been undertaken. The potential treatments were included for consideration by the City only. Further assessment by the City should also be taken to assess the condition of pavement markings. It is essential to note that the three recommended intersections should be further reviewed / visited by the RLC vendor to ensure that feasibility of RLC installation at the recommended intersections. For example, presence of metal objects or detection loops could cause interference with RLC systems.

Table 7: Summary of Field Investigation Findings and Recommendations

Intersection	Potential Issues	Potential Treatments	Recommended for RLC
Paris Street and Cedar Street	Intersections are within close proximity for all of the three approaches, thus, potential confusion to drivers on which signal to look at.	Installation of programmable signal heads / signal timing improvements.	Yes
Lorne Street and Douglas Street	Potential mixed messages maybe given to EB and WB drivers by the rail crossing flashing red light and traffic signal head.		No
	Potential signal timing / phasing issue. It was observed that protected phase is given to the NBL movement when there are no vehicles in the NBL lane.	Improvement to signal timing / phasing.	
	EB and WB secondary traffic signal heads are slightly angled. NB traffic could see the signal indications intended for EB traffic and similarly, SB traffic could see signal display intended for WB traffic; thus, it creates potential confusion to NB and SB drivers.	Adjustment / re-alignment of the signal heads.	
Notre Dame Avenue and Cambrian Heights Drive	Insufficient Stopping Sight Distance for EB traffic.	Installation of traffic signal ahead warning sign.	No
	Vegetation foliage on the southwest corner blocks EB primary signal head.	Trimming of the foliage in the southwest corner of the intersection.	
	WB signal heads are visible to drivers on the service road and this could encourage vehicles on the service road to do unsafe back-to-back maneuvers; vehicles potentially accelerate as they approach and make a careless turn to enter the intersection but as drivers make the turning maneuver, they may not realize the signal indication has changed from green to amber, and possibly red.	Install programmable signal heads for WB traffic.	

Intersection	Potential Issues	Potential Treatments	Recommended for RLC
	Potential signal visibility issue for EB traffic during the amber interval. The yellow McDonald's sign could interfere with drivers' perception of signal indications.	Potential relocation of the McDonald's sign.	
	Potential distraction because of the digital advertisement signs in the north west and north east corners.	Review the locations and the specification of the digital advertising signs using the TAC's "*Digital and Projected Advertising Displays: Regulatory and Road Safety Assessment Guidelines* (2015)".	
	Duration of all-red interval for EB may not be adequate as eastbound through drivers slow down as they enter the intersection in preparation of upcoming turning maneuvers into the service road.	Re-visit and make adjustments (if necessary) to the signal timing plan.	
Elm Street and Elgin Street	Intersections are within close proximity in the EB and NB directions, thus, causing potential confusion to drivers on which traffic signal to look at.	Installation of programmable signal heads.	No
	Located close to an at-grade rail-road crossing. Potential mixed messages maybe given to WB drivers by the rail crossing flashing red light and green display on traffic signal head	Interconnect traffic signals with the rail crossing warning system.	
	The nearside traffic signal head could block NB primary signal head		
	Potential signal timing / phasing issue. Protected phase is given to NBL and SBL movements when there are no vehicles in the NBL and SBL lanes.	Improvement to signal timing / phasing.	
Municipal Road 80 and Dominion Drive	Vegetation foliage at the northeast corner blocks WB primary signal head.	Trimming the foliage at the northeast corner.	Yes
	Street name sign mounted on the nearside traffic pole cantilever blocks WB secondary signal head.	Relocation of the street name sign.	
Regent Street and Algonquin Road			Yes
Regent Street and Beatty Street	EB curb lane drop require last minute lane changes within a short distance to the intersection.		No
	Potential sight line issue for NBR and WBR.	Installation of no right turn on red sign.	
	Potential signal timing / phasing issue. Protected phases are given to WBL and NBL movements even when there is no demand.	Improvement to signal timing / phasing.	

5. Conclusions and Recommendations

The summary of findings and recommendations of this study are as follows:

- There is a need and justification for installation of RLCs in the City of Greater Sudbury as there are a total of 55 signalized intersections that potentially benefit from RLC installations.

- The three recommended intersections for RLC installations were identified as those that would benefit the most from installation of RLCs. The three recommended intersections are:
  - Paris Street and Cedar Street;
  - Municipal Road 80 and Dominion Road; and
  - Regent Street and Algonquin Road.

- The three recommended intersections for RLC installations should be further reviewed / visited by the RLC vendor to ensure that feasibility of RLC installation at the recommended intersections.

- At four of the candidate intersections that were not recommended for RLC installations, a number of potential engineering solutions should be considered for implementation and assessed for effectiveness, prior to reconsidering RLC installation.

- The overall safety effectiveness of an RLC program could be increased by increasing the number of installation sites. In such a case, office and field reviews similar to those completed in this study should be undertaken for additional candidate sites.

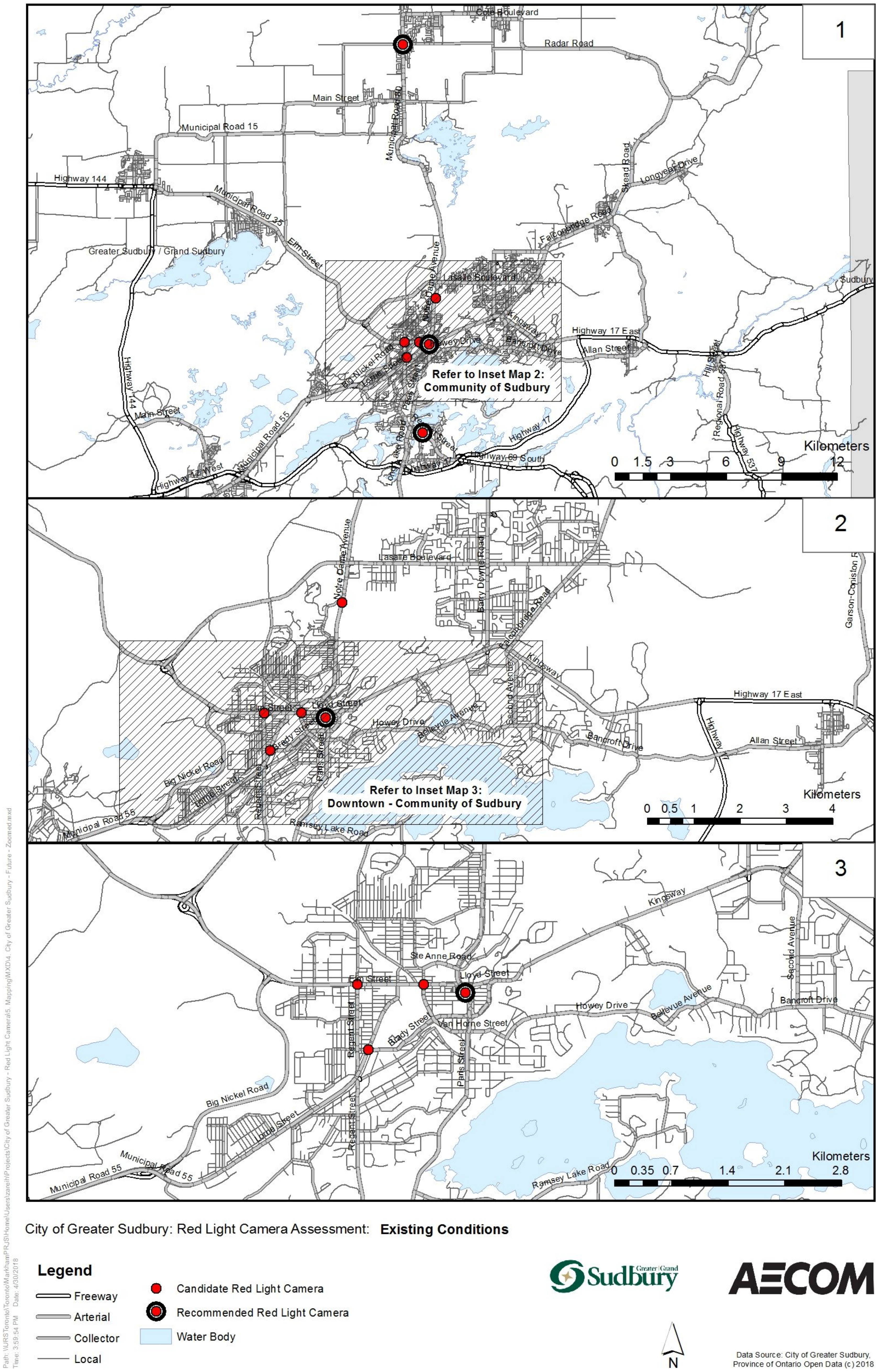

Figure 6: Candidate and Recommended Intersections for RLC Installations

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Appendix A : Methodology to Develop Safety Performance Functions

Safety Performance Function for 4-Legged Intersections

For the purpose of this study, the negative binomial generalized linear model package in R statistical software was used as a tool in the development of the SPFs. For each of the dependent variables (i.e., frequency of collision impact types), SPFs with different model forms were calibrated. The candidate SPF model forms considered in this study were those that most often had appeared in the literature for signalized intersections with similar traffic volumes and number of approaches. These SPF model forms were evaluated using various criteria.

The first criterion was the presence of a counter-intuitive sign for variable coefficients (‘β_1’ and ‘β_2’), which immediately resulted in the rejection of the model. The second criterion was the statistical significance of the coefficients. Only models for which all coefficients were statistically significant at a 95% confidence level were accepted. The third criterion was the over-dispersion parameter (‘k’), which was used as an overall goodness-of-fit measure. A lower value of the over-dispersion parameter (‘k’) represents a better fit of the model. Finally, the fourth criterion was the mean Pearson’s Chi-Square $(X)^2$ statistical measure. This measure is calculated using the following equations, where d_f represents the degrees of freedom of the model:

$$X^2 = \sum_{i=1}^{n} \sum_{t=1}^{T} \frac{[Y_{it} - E(Y)]^2}{Var(Y)}$$

Where, Y_{it} is the observed collision frequency for intersection i in year t,
E(Y) is the expected value of collision frequency corresponding to Y_{it} obtained from the SPF model,
$Var(Y)$ is the variance of collision frequency,
n is the number of intersections, and
T is the study period.

The variance of negative binomial distribution is given by the following equation:

$$Var(Y) = \mu + k\mu^2$$

Where: *y* is the random variable that represents the collision frequency at a given location at a specific period of time
μ is the Predicted collision frequency
k is the dispersion parameter

A value of $X^2{}_{mean}$ closer to 1 indicates a better goodness-of-fit of the model.

The third and fourth criteria were jointly used to assess the overall goodness-of-fit of the model. In this assignment, if the first two criteria for goodness-of-fit were satisfied (i.e., the signs for the model coefficients were all intuitive and coefficients were statistically significant) then the SPF model form with the smallest over-dispersion parameter (‘k’) and $X^2{}_{mean}$ statistics closer to 1 was selected. The database contained 114 intersections; among them 94 were 4-legged intersections. The selected SPF model form for 4-legged intersections in this study was as follows:

$$E(Y) = \alpha * (MajorAADT + MinorAADT)^{\beta_1}$$

Where, $MajorAADT$ is the entering AADT from the major road,
$MinorAADT$ is the entering AADT from the minor road,
α, β_1 are the model parameters

Safety Performance Function for 3-Legged Intersections

As mentioned above, the database contained 114 intersections, among them, 20 were 3-legged intersections. Statically significant models could not be found, as such, a statically significant predictive model was borrowed from the Highway Safety Manual (HCM) and calibrated for application in the city of Greater Sudbury. In this procedure, the calibration factor (C) is the total number of collisions observed in a sample from one jurisdiction divided by the sum of the predicted number of collisions using the model from another jurisdiction. The calibration factor is calculated as follows:

$$Calibration\ factor\ (C) = \frac{\sum_{i=1}^{n} Y_i}{\sum_{i=1}^{n} \hat{Y}_i}$$

Where: Y_i is the observed number of collisions for year i
$\hat{Y}_i$ is the predicted number of collisions for year i using the HCM model

The SPF model form for 3-legged intersections in this study was as follows:

$$E(Y) = \alpha * (MajorAADT)^{\beta_1} * (Minor\ AADT)^{\beta_2}$$

Where, $MajorAADT$ is the entering AADT from the major road,
$MinorAADT$ is the entering AADT from the minor road, and
α, β_1, β_2 are the model parameters.