

Summary Report - Implications and Results of Protected Only Left Turn Signals

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Executive Summary

The objective of this report is to clarify the process in which traffic signals are designed and the methods used to warrant specific traffic signal phases. This report covers the effects and benefits to the transportation network for the implementation of protected-only left turn traffic signal phases and the measurable impacts and benefits to the transportation network.

Strathcona County's current left turn operation guidelines are consistent when compared to those adopted by other government agencies in Alberta and are recommended to remain in place. Left turn lane movements operated with permissive signal phasing often create safety issues for driver decisions and judgment of safe gaps in oncoming traffic. As a result of safety issues, through recorded crashes, protected-only left turn signal phasing should be implemented on dual left turn lanes that meet the warrant criteria, to improve safety by reducing the likelihood of crashes. Ongoing traffic signal analysis and field inspections are to be carried out to ensure all left turn signal phase operations are safe and promote driver understanding.

The implementation of protected-only left turn signal phasing has reduced crashes on average 78% in Strathcona County immediately after their implementation with additional reductions still anticipated as driver familiarity continues to improve. There are negative impacts to the efficiency of an intersection due to the implementation of protected-only left turn signal phasing, especially in the off peak hours due to low oncoming traffic volumes. The intermittent use of different left turn signal phases at one intersection is not possible due to the hard-wired nature of the signal lights within the traffic controller. The implementation of protected-only signal phasing is only recommended when the specific warrant criteria have been met.

There has not been an indication of increased incidences of speed on green behaviour upon the installation of protected-only left turn signals. No additional shortcutting traffic has been measured or can be attributed to the implementation of protected-only left turn signal phasing or any other arterial road impacts. The adoption of Safe Systems principles and philosophies developed in the Traffic Safety Strategy Plan 2020 (TSSP 2020) is in the process of reviewing left turn signal operations to define necessary changes in the geometry configurations, signal phasing, and timings for safer and more effective signal operations.

As protected-only left turn signals are restrictive and cause delays to left turn traffic especially during low peak and night hours, the County installs this type of signal only when absolutely necessary. The goal is to provide sufficient green times on protected-only left turn phases to allow all left turning traffic within the queue to clear during the first signal cycle. Strathcona County follows the "Left Turn Signal Assessment Warrant Guidelines" and "Policy SER-009-021 – Installation of Traffic Signals and Pedestrian Crossings" to install and operate protected-only left turn signals. A complete signal retiming is being undertaken for the entire traffic signal network in the summer of 2017 and will be designed to address current traffic volumes, patterns, and demands.

Contents

1.0	Introduction	1
2.0	Left Turn Signal Warrants	2
2.1.	Intersection Design and Characteristics	2
2.2.	Sight Distance Issues	2
2.3.	Left Turn Movements with High Crash Records	2
2.4.	Literature Review	3
3.0	Dual Left Turn Lane Operational Issues in Alberta	4
3.1.	Sight Distance Restriction	4
3.2.	Crashes	6
3.3.	Failing to Yield to Oncoming Traffic	6
4.0	Strategies to Manage Left Turn Safety Concerns	7
4.1.	Change Left Turn Signals to Protected-only	7
4.2.	Closing One of the Dual Left Turn Lanes.....	9
4.3.	Change the Sequencing of the Opposing Left Turn Phases	9
5.0	Safety – Collision Review	10
6.0	Speed on Green and Shortcutting Traffic.....	12
7.0	Conclusions and Recommendations	12
Appendix A	Left Turn Signal Assessment Warrant Guidelines	13

List of Figures

Figure 1 The view of one left turner is blocked by another left turner

Figure 2 Opposing left turn lanes: negative offset; no offset and positive offset

Figure 3 Visibility issue caused by westbound dual left turn lanes

Figure 4 Installation of "Left Turn Yield on Green" signs

List of Tables

Table 1 High left turn across path crash locations

Table 2 Jurisdictional warrant criteria for protected-only left turn signals

Table 3 Permissive dual left turns with operation issues

Table 4 Proposed protected-only left turn signals with dual left lanes

Table 5 Dual left turn lanes to be converted to single left turn lane

Table 6 Implementation history of protected-only left turn phasing

Table 7 Left turn across path collision history

1.0 Introduction

The objective of this report is to provide information, benchmarking, and guidance for the process in which traffic signals are designed and the methods that are used to warrant specific traffic signal phase designs. This report will define the effects and benefits to the transportation network as a whole with the implementation of protected-only left turn signals, including the safety improvements in regards to collisions, neighbourhood impacts, and the effects on driver behaviour.

The protected-only left turn signal has not been widely used in North America due to its restrictive operation on the overall efficiency of an intersection. Therefore, most government agencies implement protected-only phasing when a single left turn lane is no longer able to accommodate safe left turning traffic, exhibiting disproportionately high numbers of crashes. Traffic volumes on average are increasing and pressuring the design capacity of many intersections during peak travel times. These overcapacity intersections are being designed to operate multiple left turn lanes in order to accommodate additional traffic. As an example, double and even triple left turn lanes with protected-only signals have been widely installed by many government agencies throughout the United States. The impacts of arterial traffic signal design can have tertiary impacts to surrounding neighbourhoods in driver behaviour to shortcut through neighbourhoods in an effort to avoid traffic signals.

The addition of left turn signal phases requires additional green time, therefore taking away overall cycle time and reducing the efficiency of the intersection. As a result of the reduced green time, traffic signal engineers ensure the intersection operates efficiently to accommodate all traffic movements. For the past several decades, more left turn operations have been changed to protected-only left turn signals due to the increase in traffic volumes and the increase of left turn across path crashes. The practice of implementing protected-only left turn signals on dual left turn lanes is quickly becoming the industry best practice and is widely accepted by many government agencies in Alberta as the most appropriate method to manage traffic through signalized intersections in a safer manner. The issue of drivers speeding up to get through an intersection to avoid getting delayed by longer signal times is an issue that has been observed for many years and is a function of driver behaviour that can be addressed through various education and enforcement methods.

The left turn across path crash is one of the most negatively impactful crash types due to the high velocities and vulnerability of the passengers inside of the vehicle space. In other words, left turn across path collisions have a high likelihood for serious and fatal outcomes and are to be prevented and eliminated in order to improve the safety of the transportation network in a safe system compliant manner.

Planning and Development Services and Transportation Planning and Engineering departments of Strathcona County work together to implement left turn lanes and signals where and when they are required within the County. The installation of left turn facilities within the County is based upon the following County Policy and Guidelines in conjunction with the design and construction standards, which also follow nationally-accepted best practices in North America:

- Left Turn Signal Assessment Warrant Guidelines; and
- Policy SER-009-021 – Installation of Traffic Signals and Pedestrian Crossings

The County's current guidelines were updated in 2017 and are included in Appendix A.

2.0 Left Turn Signal Warrants

A protected-only left turn signal will be designed and implemented by Strathcona County when certain warrant criteria are met for any given intersection.

- Intersection characteristics – high speed corridors, intersection size, and geometry
- Inadequate sight distance – dual left turn lanes, vertical curve, and obstructions
- Record of historical crash data

2.1. Intersection Design and Characteristics

The implementation of a protected-only signal is warranted when the number of opposing through lanes and the posted speed limit present a safe system concern and the need to prevent the potential for serious crashes exists. As an example, the geometry of the intersection at Wye Road west of Sherwood Drive (to access the Safeway store), meets the warrant criteria for a protected-only left turn signal. In this case, eastbound left turning traffic crosses four westbound through lanes in a posted 70km/hr speed limit.

2.2. Sight Distance Issues

The nationally-accepted best practice for the operation of protected-only left turn signals at dual left turn lanes has been accepted due to the restriction of sightlines and re-occurring collision history. Over the past decade, Alberta Transportation and other Alberta municipalities, including the Cities of Edmonton and Calgary have followed the nationally-accepted best practice to proactively implement protected-only left turn signals in order to prevent unsafe left turns at signalized intersections.

2.3. Left Turn Movements with High Crash Records

Left turn signals will be upgraded if there is a high record of left turn across path crashes associated with permissive left turns. The adoption of Safe Systems principles and philosophies developed in the Traffic Safety Strategy Plan 2020 (TSSP 2020) aims to minimize or eliminate left turn across path collisions.

Based upon up to date crash data, two left turn movements with a single left turn lane have been identified as intersections of concern for high numbers of left turn across path collisions, meeting the safety warrant for protected-only left turn signals:

No.	Intersection	Left Turn Direction	Number of Crashes over a 3-year Period
1	Fir Street and Sherwood Drive	Northbound	17
2	Baseline Road and Brower Drive (Glenbrook Boulevard)	Westbound	12

Table 1 – High left turn across path crash locations

The left turn operation at these locations will continue to be monitored with changes pending should safety issues persist.

2.4. Literature Review

Several major government agencies in Alberta were contacted to gather information regarding established warrant criteria's for the implementation of protected-only left turn signals in their jurisdictions.

Table 2 summarizes signal warrant criteria adopted by these government agencies in Alberta as well as the Federal Highway Administration (FHWA) in the US.

Jurisdiction	Protected-Only Left Turn Signal Warrant Criteria		
	Geometry Opposing Through lanes	Sightline Dual Left Turn Lanes	Safety Left Turn Across Path
Strathcona County	<ul style="list-style-type: none"> • 4 or more through lanes with posted speed 70km/h or greater 	YES (in the process of converting left turn signals)	<ul style="list-style-type: none"> • 5 or more per year • 8 or more in any consecutive 2-year period within last 3 years
Alberta Transportation	<ul style="list-style-type: none"> • 3 or more through lanes with posted speed 70km/h or greater 	YES	<ul style="list-style-type: none"> • Left turn movements with high collision records
City of Edmonton	<ul style="list-style-type: none"> • 3 or more through lanes with posted speed 70km/h or greater 	YES (in the process of converting left turn signals)	<ul style="list-style-type: none"> • 15 or more over a 3-year period
City of St. Albert	<ul style="list-style-type: none"> • 1 or more opposing through lanes with posted speed 100km/h or greater • 2 or more opposing through lanes with posted speed 90km/h or greater • 3 or more opposing through lanes with posted speed 80km/h or greater 	YES (all signals are protected-only)	<ul style="list-style-type: none"> • 2 or more over a 2-year period
City of Calgary	<ul style="list-style-type: none"> • 1 or more opposing through lanes with posted speed 100km/h or greater • 2 or more opposing through lanes with posted speed 90km/h or greater • 3 or more opposing through lanes with posted speed 80km/h or greater 	YES (all left turn signals are protected-only)	<ul style="list-style-type: none"> • 4 left turn collisions per year over 3 years
City of Red Deer	<ul style="list-style-type: none"> • 3 or more opposing through lanes with posted speed 80km/h or greater • 4 or more opposing 	YES Monitoring if the opposing through traffic is extremely low	<ul style="list-style-type: none"> • 7 or more over a 3-year period

Jurisdiction	Protected-Only Left Turn Signal Warrant Criteria		
	Geometry Opposing Through lanes	Sightline Dual Left Turn Lanes	Safety Left Turn Across Path
	through lanes of traffic		
City of Lethbridge	<ul style="list-style-type: none"> Through lanes with posted speed 80km/h or greater 	YES for newly opened dual left turn lanes. Monitoring the collision statistic on existing dual left turn lanes	<ul style="list-style-type: none"> 4 or more per year
FHWA	<ul style="list-style-type: none"> 3 or more opposing through lanes with posted speed 80km/h or greater 	YES	<ul style="list-style-type: none"> 4 or more per year 6 or more over a 2-year period 8 or more over a 3-year period

Table 2 – Jurisdictional Warrant Criteria for Protected-Only Left Turn Signals

As summarized in Table 2, the County's warrant criterion is similar to other jurisdictions in Alberta as well as the FHWA. Strathcona County's goal is to implement protected-only left turn signals only when absolutely necessary to reduce the likelihood of left turn across path crashes.

3.0 Dual Left Turn Lane Operational Issues in Alberta

Over the past decade, government agencies in Alberta, including Strathcona County, have started to monitor dual left turn lane operations because of the increase in crashes. An indication that permissive and protected-permissive left turn signals are no longer functioning at an acceptable level can be defined when three common operational issues are recorded:

1. Inadequate sight distance
2. Left turn across path crashes
3. Observed driver behaviour – close calls with left turning traffic failing to yield to through traffic as reported by drivers

3.1. Sight Distance Restriction

Appropriately designed sight distances and geometry are key factors in the safe operation of an intersection. Lane configuration for dual left turn lane operations creates a potential visibility issue in two ways.

First, sightline issues are created between the two left turning vehicles going in the same direction. The view of the left turning driver on the inside lane is obstructed by the left turning vehicles on the outside lane as observed in Figure 1. A protected-only left turn signal allows left turning drivers to turn without the need to judge and assume safe gaps in oncoming traffic.



Figure 1 The view of one left turner is blocked by another left turner

The second sightline issue is created by the alignment of two opposing left turn lanes. Opposing left turn lanes are typically aligned across from one another immediately adjacent to through lanes, as shown in case (b) of Figure 2. A waiting left turning vehicle on the opposing left turn lane can obstruct the view of oncoming through vehicles. The majority of intersections in Sherwood Park are designed with the opposing left turn lanes aligned directly to each other, causing only a sightline issue, case (b). The issue is further challenged by converting single left turn lanes to dual left turn lanes as shown in case (a). Sightlines can be improved by providing positive offset left turn lanes as in case (c)

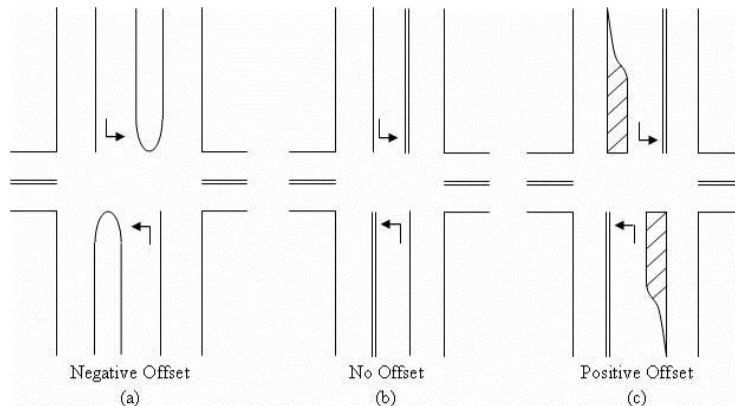


Figure 2 Opposing left turn lanes: Negative offset; no offset and positive Offset

Based upon 2016 crash records, the eastbound left turn movement at the intersection of Wye Road and Ash Street has six recorded left turn across path crashes. This collision history is unexpected and can be attributed to the sightline of the eastbound left turning vehicles being obstructed by the waiting westbound left turning vehicles opposing them; as shown in Figure 3. In a case such as this, the sightline issue can be corrected by closing the outside left turn lane for the westbound left turn movement until the lane is needed to support higher volumes of traffic.

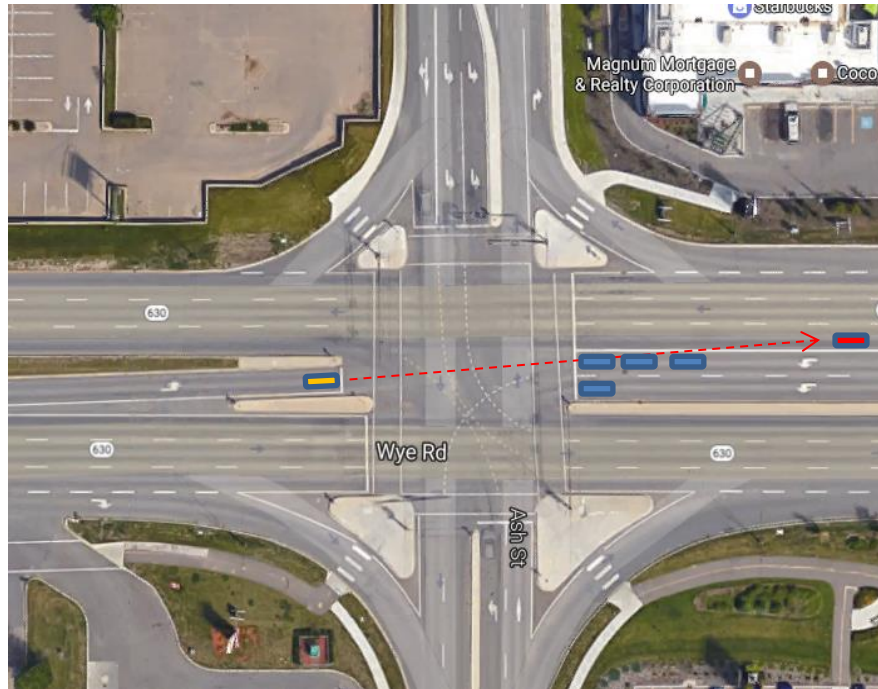


Figure 3 Visibility issue caused by westbound dual left turn lanes

3.2. Crashes

The left turn across path crash often occurs during the permissive green phase and the inter-green (e.g., amber and all-red times) phases where left turning drivers fail to judge and assume adequate gaps in the opposing through traffic to safely cross the intersection. A protected-only left turn signal phase provides left turning drivers piece of mind when turning, therefore preventing crashes.

Based upon crash records between 2011 and 2016, the westbound left turn movement for the intersection of Sherwood Drive and Brentwood Boulevard has 29 left turn crashes recorded. This intersection signal phasing design has been reviewed and implemented to improve safety at this intersection.

3.3. Failing to Yield to Oncoming Traffic

Double left turn lanes designed with permissive green phases have a tendency to create failing to yield to oncoming through traffic. Government agencies have installed "Left Turn Yield on Green" signs to remind drivers to yield to opposing through traffic. This issue occurs often when the dual left turn movement is very heavy and the opposing through traffic is very light. The County has received complaints of this type of driving behaviour shown in table 3.

No.	Intersection	Left Turn Direction	Current Signal Phasing
1	Scotford North Signal	Northbound	Permissive
2	Lakeland Drive and Premier Way	Southbound	Permissive
3	Granada Boulevard and Sherwood Drive	Westbound	Protected-Permissive

Table 3 – Permissive dual left turns with operation issues

Figure 4 shows that the northbound dual left turn operation with protected-permissive left turn signals at a Scotford industrial area intersection. Three static "Left Turn Yield on Green" signs have recently been installed to address safety concerns raised by commuters. The purpose of the signs is to remind left turning drivers to yield to oncoming southbound through traffic during the permissive green signal.



Figure 4 Installation of "Left Turn Yield on Green" signs

4.0 Strategies to Manage Left Turn Safety Concerns

Strathcona County uses the Traffic Crash Location System (TCLS Software) to track and monitor the safety of the entire transportation network. A function of this review is that of the performance for each left turn movement at signalized intersections.

The County has developed a work plan to change left turn signal designs to best fit the transportation network and provide a safe and efficient environment for all road users:

1. Change left turn signals to protected-only to prevent conflicts and crashes
2. Close one of the dual left turn lanes to improve sightlines
3. Review and change the sequencing of the opposing left turn signals

4.1. Change Left Turn Signals to Protected-only

As overall traffic volumes in Sherwood Park have increased, the number of left turn across path crashes has also risen. As a result, the County recognizes the need to adapt and implement protected-only left turn signals to prevent left turn across path crashes.

Below is a list of proposed intersections that have dual left turn lanes with heavy left turn volumes:

No.	Intersection	Left Turn Direction	Current Signal Phasing	Actions
1	Baseline Road and	Northbound	Protected-	Left turn signal to be

No.	Intersection	Left Turn Direction	Current Signal Phasing	Actions
	Broadmoor Boulevard		Permissive	upgraded in future
2	Baseline Road and Sherwood Drive	Northbound	Protected-Permissive	Left turn signal to be upgraded in future
3	Baseline Road and Clover Bar Road	Northbound	Protected-Permissive	Left turn signal to be upgraded in future
4	Lakeland Drive and Premier Way	Southbound	Permissive	Left turn signal to be upgraded in future
5	Emerald Drive and Sherwood Drive	Westbound	Permissive	Left turn signal to be upgraded in future
6	Lakeland Village Boulevard and Clover Bar Road	Eastbound	Permissive	Left turn signal to be upgraded in future
7	Lakeland Village Boulevard and Clover Bar Road	Northbound	Permissive	Left turn signal to be upgraded in future
8	Granada Boulevard and Sherwood Drive	Westbound	Protected-Permissive	Left turn signal to be upgraded in future
9	Wye Road and Brentwood Boulevard	Eastbound	Protected-Permissive	Left turn signal will be upgraded during intersection rehabilitation in 2017
10	Wye Road and Brentwood Boulevard	Southbound	Protected-Permissive	Left turn signal will be upgraded during intersection rehabilitation in 2017
11	Wye Road and Clover Bar Road	Eastbound	Protected-Permissive	Left turn signal will be monitored and upgraded during intersection rehabilitation in future
12	Wye Road and Clover Bar Road	Southbound	Protected-Permissive	Left turn signal will be monitored and upgraded during intersection rehabilitation in future

Table 4 Proposed protected-only left turn signals with dual left lanes

During the implementation of protected-only left turn signals, the Traffic Signal and ITS Engineer follows specific steps to ensure the new signal operations are operating properly, safely and efficiently.

1. Model the proposed left turn signal operation using a specialized traffic signal modelling software, Synchro;
2. Design new signal timings to provide efficient signal operation for the intersection;
3. Implement and monitor actual signal operation and adjust timings as required;
4. Work with the public to address concerns regarding the revised signal phasing;

Although protected-only left turn signals achieve well documented safety benefits, the phasing is not efficient during off peak and nighttime hours. Left turning traffic cannot proceed even though there is limited oncoming through traffic and are therefore required to

wait for the left turn phase of the next signal cycle. Unfortunately, no standard has been established to support the use of alternating left turn signal operations for different times of the day at the same intersection. Left turn signal fixtures are hard-wired and hard-coded within the traffic signal controller for 24-hour operations and are physically not able to be changed to accommodate alternating phasing cycles. Manually alternating signal phase on a daily basis requires high implementation cost and man power, which cause this operation financially impossible to be sustained.

4.2. Closing One of the Dual Left Turn Lanes

Strathcona County has been installing dual left turn lanes to accommodate future, projected growth of left turning volumes. As previously described, dual left turn lanes often create operational and safety issues without the use of protected-only left turn signals. Implementing protected-only left turn signal phasing prematurely with low volumes of traffic, introduces unnecessary and misunderstood delays to the motorists. In order to reduce the need to implement protected-only left turn phasing, one of left turn lanes can be closed until traffic volumes warrant the need for dual left turn lanes. A single left turn lane permits the existing permissive left turn signal phasing to be maintained.

Table 5 shows a list of proposed intersections that have dual left turn lanes with low left turn volumes and the proposed or taken actions:

No.	Intersection	Left Turn Direction	Actions
1	Lakeland Drive and Broadmoor Boulevard	Northbound	Outside left turn lane was closed in 2016 before opening.
2	Lakeland Drive and Broadmoor Boulevard	Eastbound	Outside left turn lane to be closed in future
3	Wye Road and Ash Street	Westbound	Outside left turn lane to be closed in summer 2017
4	Wye Road and Mitchell Street	Westbound	Outside left turn lane to be closed in summer 2017
5	Emerald Drive and Sherwood Drive	Eastbound	Outside left turn lane to be closed in summer 2017
6	Amberley Way and Sherwood Drive	Westbound	Outside left turn lane to be closed in summer 2017
7	Lakeland Drive and Palisades Way	Northbound	Outside left turn lane to be closed during opening
8	Emerald Drive and Sherwood Drive	Southbound	Outside left turn lane to be closed during opening
9	Summerwood Boulevard and Clover Bar Road	Westbound	Outside left turn lane to be closed in future
10	Lakeland Drive and Broadmoor Boulevard	Westbound	Outside left turn lane to be closed and to be re-opened if there is a need for detour purposes.

Table 5 Dual left turn lanes to be converted to single left turn lane

4.3. Change the Sequencing of the Opposing Left Turn Phases

A review of the operation of existing left turn signal phasing is occurring to evaluate changing the "lead-lag" left turn phasing to "lead-lead" left turn phasing in order to improve the safety and function of intersections and corridors.

Opposing left turn signals can be implemented in the following sequences:

- Lead-Lead: Both left turn signals come on before the through signals
- Lag-Lag: Both left turn signals come on after the through signals
- Lead-Lag : One left turn signal comes on before and the other comes on after the through signals

Most of the opposing left turn signal sequences implemented within Sherwood Park are “lead-lead” because it is the most familiar to the general public. However, “lead-lag” phasing at certain intersections has been implemented to address the geometric limitations of intersections upon the implementation of dual left turn lanes. When dual left turn lanes are added to an intersection, the intersection is too small to accommodate the space required by the dual left turning traffic. Without separating the opposing left turn movements, opposing vehicles are lined up for the possibility of “head-on” crashes and the lead-lag phase is required to eliminate the safety risk of a crash. Driver unfamiliarity with “lead-lag” signal phasing may confuse and have a higher risk of failing to observe and obey the traffic signal. If the geometric limitations are removed, “lead-lead” left turn signal phasing can be restored.

5.0 Safety – Collision Review

The safety benefit of protected-only left turn signal phases at intersections in Sherwood Park is measured in the total number of left turn across path crashes at each intersection, when comparing the before and after implementation results. For the purpose of this report, six primary intersections were reviewed for before the implementation of protected-only left turn signal phasing and after the implementation. Table 6 shows the history left turn protected-only phasing implementation dates.

Intersection	Movement	Implementation Date
Baseline Road and Broadmoor Boulevard	EBL/WBL	October 2005
Baseline Road and Sherwood Drive	EBL/WBL	October 2005
Baseline Road and Clover Bar Road	EBL/WBL	July 2012
Baseline Road and Chippewa Road	EBL/WBL	August 2014
Wye Road and Sherwood Drive	EBL/WBL	September 2014
Sherwood Drive and Brentwood Boulevard	WBL	February 2016

Table 6 Implementation history of protected-only left turn phasing

Collision history was reviewed for left turn across path where left turn was protected. Table 7 shows the average number of collisions per year and the corresponding percent reduction.

Intersection	Movement	Collisions per Year				% Reduction
		Before		After		
Baseline Road and Broadmoor Boulevard	EBL/WBL	5 Years (2001-05)	6.0	11 Years (2006-16)	2.5	59.1%
Baseline Road and Sherwood Drive	EBL/WBL	5 Years (2001-05)	5.0	11 Years (2006-16)	2.2	56.0%
Baseline Road and Clover Bar Road	EBL/WBL	11 Years (2001-11)	10.6	5 Years (2012-16)	0.2	98.1%
Wye Road and Sherwood Drive	EBL/WBL	14 Years (2001-14)	9.4	2 Years (2015-16)	2.0	78.6%
Baseline Road and Chippewa Road	EBL/WBL	14 Years (2001-14)	2.1	2 Years (2015-16)	0.5	76.7%
Sherwood Drive and Brentwood Boulevard	WBL	5 Years (2011-15)	5.0	1 Year 2016	0.0	100.0%
Average Crash Reduction						78.1%

Table 7: Left turn across path collision history

Sherwood Drive and Brentwood Boulevard has the highest reduction of left turn across path crashes in the westbound direction since the phasing was changed. There were 29 crashes in last 5 years (2011-2016); averaging 5.8 crashes per year. Left turn across path crashes have been eliminated after the protected-only left turn signal implementation.

Baseline Road and Clover Bar Road has the highest incidents of left turn across path crashes averaging 10.6 collisions per year before the change, including one fatal and a major injury collision before the change. Since the implementation of the protected-only left turn phase in the eastbound and westbound directions there has been one collision reported since 2012.

Similarly Wye Road and Sherwood Drive had a history of left turn across path crashes averaging 9.4 collisions per year. Since the implementation of protected-only left turn phasing, crashes have reduced to an average of two per year.

According to the FHWA's Highway Safety Manual, Crash modification factors for the implementation of protected-only left turn phasing from permissive signal phasing for an urban signalized intersection is 0.94. The 0.94 factor represents an expected 94 percent reduction in crashes, therefore additional improvements are still expected in the County.

According to a 2010 study conducted by the Capital Region Intersection Safety Partnership (CRISP) there is an economic cost associated with traffic collisions. The direct collision cost for a Property Damage Only (PDO) collision averages \$10,900. The costs for an injury collision averages \$39,500. These direct costs are much easier to approximate than the pain and suffering, social costs associated with vehicle collisions, injuries, and deaths.

In the protected-only left turn signal phase, drivers not permitted to proceed on red lights, therefore legally ensuring left turn across path collisions are not possible. As shown in the research, there are recorded collisions in the after period, which shows that the driver in those cases disobeyed the traffic laws to run a red light resulting in the crash. It is not possible to know why a driver disobeyed a traffic law however as drivers become more familiar with the protected-only traffic light signal phasing, government agencies do anticipate fewer and fewer instances occurring from these unforeseen crashes.

6.0 Speed on Green and Shortcutting Traffic

The issue of drivers accelerating to get through an intersection is not new and has been a driver awareness and behaviour issue that both engineering and enforcement have understood for many years. From an engineering perspective, signals are designed to accommodate the average volume of vehicles for any given moment in time. At times drivers will simply miss the timing of a signal cycle and be forced to wait for the next cycle or elect to disobey posted speed limits and red light running laws to get through an intersection. This "speed on green" phenomenon is a driving behaviour that opposes traffic laws and is a function of the decisions being made by an individual regardless of the type and function of the traffic signal fixtures installed.

From an enforcement perspective, the Intersection Safety Device (ISD) or red light and speed on green cameras have been developed and used successfully to enforce traffic laws at intersections. In Strathcona County, the use of ISD devices has been implemented on high risk intersections to encourage appropriate driver behaviour. The ISD devices have been successful at improving driver compliance with existing traffic laws, therefore improving the safety of intersections.

Based upon a cursory review of collisions and infractions in the County, there has not been an indication of increased incidences of speed on green behaviour upon the installation of protected-only left turn signals.

A review of vehicle volumes on local and collectors roads near and around arterial intersections with protected-only left turn phasing does not indicate an increase in shortcutting traffic to avoid traffic lights. Every effort is made during the design and implementation of signals to have coordinated signal timings through corridors to reduce the appeal of shortcutting through residential neighbourhoods. Current travel times show positive corridor travel times during peak hours and indicate that shortcutting through neighbourhoods rather than traveling on the arterial road network would not improve travel times.

7.0 Conclusions and Recommendations

Strathcona County's current left turn operation guidelines are consistent when compared to those adopted by other government agencies in Alberta and are recommended to remain in place. Left turn lane movements operated with permissive signal phasing often create safety issues for driver decisions and judgment of gaps in oncoming traffic. As a result of safety issues, through recorded crashes, protected-only left turn signal phasing should be implemented on dual left turn lanes that meet the warrant criteria for crashes, to improve safety by reducing the likelihood of crashes. Ongoing traffic signal analysis and field inspections are to be carried out to ensure all left turn signal phase operations are safe and promote driver understanding.

The implementation of protected-only left turn signal phasing reduces crashes on average 78% immediately after implementation with additional reductions still anticipated as driver familiarity continues to improve. There are negative impacts to the efficiency of an intersection due to the implementation of protected-only left turn signal phasing, especially in the off peak hours due to low oncoming traffic volumes. The alternating use of different

left turn signal phasing at one intersection is not possible due to the hard-wired nature of the signal lights within the traffic controller. The implementation of protected-only signal phasing is only recommended when the specific warrant criteria have been met.

There has not been an indication of increased incidences of speed on green behaviour upon the installation of protected-only left turn signals. No additional shortcutting traffic has been measured or can be attributed to the implementation of protected-only left turn signal phasing or any other arterial road impacts. A complete signal retiming is being undertaken for the entire traffic signal network and will be designed to address current traffic volumes, patterns, and demands.