Rectangular Rapid Flashing Beacon (RRFB) Pilot Project Summary Report

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EXECUTIVE SUMMARY

The Rectangular Rapid Flashing Beacon (RRFB) is a potential alternative to traditional pedestrian activated overhead beacon systems used at pedestrian crossings. The City of Calgary has undertaken an RRFB Pilot Project to assess motorist yielding behaviour at locations with RRFBs. The project also tested the reliability of solar battery systems used to power the RRFBs.

Initially two RRFB systems were purchased from each of the four suppliers who responded to a Request for Proposal (RFP). One additional system was purchased in spring 2013 for additional testing.

The results of the motorist yielding behaviour performance were completed for eight locations and showed increases at all locations. The before studies yielding behaviour at the study locations was 74%-94% and in seven of eight locations, yielding was increased to near 100% (96%-100%). The eighth location yielding increased to 90%.

Solar power has proven to be an unreliable method of powering these devices in Calgary. To address this, it is recommended that current RRFBs be connected to continuous power. Alternate power sources, such as street light power to supplement solar power, and other methods may also be investigated for future installations. Installation of an RRFB at a ninth location is currently underway to test the use of streetlight power as a supplement to solar power.

The approximate cost to install a traditional pedestrian-activated overhead flasher system with a continuous power supply is site specific in the range of $70,000 to $95,000. The costs to install an RRFB in the trial locations ranged from $15,000 to $40,000. The cost to connect the trial location RRFB’s to a continuous power supply is estimated at $10,000 to $25, 000. The total costs for the trial RRFB locations including estimates of connection to continuous power range from $25,000 to $66,000.

The Transportation Association of Canada has approved a project, being lead by The City of Calgary, to develop standards and guidelines for implementation of RRFBs. It is expected that guidelines will be available by the spring of 2014.

Recommendations resulting from the RRFB Pilot Project are:

- Retrofit current RRFBs to connect to AC power to increase their reliability,
- Continue to test solar technologies as they become available to determine if they are suited for use with traffic control devices in Calgary, and
- Develop an implementation program for RRFBs once TAC guidelines are completed.

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1. INTRODUCTION

The City of Calgary has undertaken the Rectangular Rapid Flash Beacon (RRFB) Pilot Project to assess motorist yielding behaviour and the performance of the solar power system. The methodology and findings of the RRFB Pilot Project are described in this report.

Eight solar powered RRFBs were installed for the trial in 2012. The eighth location is a replacement for an originally planned location that was later found to be unsuitable for an RRFB. A ninth location is planned to be installed in 2013. The RRFBs were installed at locations with existing signed and marked crosswalks. Driver yielding behaviour was compared before and after installation of the RRFBs.

The pilot occurred over a one-year period, beginning in May 2012. Details regarding the yielding improvement, effectiveness of the solar power, and recommendations for future studies are summarized in this report.

Funding in the amount of $200,000.00 for the RRFB Pilot Project was provided by the Mayor's Innovation Fund. The goal of the project was to test new and innovative technology in Calgary conditions and this has been achieved. It was not a goal of the pilot project to specifically compare products from different vendors and to select a particular product for future use. As detailed in Section 7 of this report, a project is currently being undertaken by the Transportation Association of Canada to develop specifications and guidelines for RRFBs that could be used to select specific systems for future use in Calgary.

2. BACKGROUND

Passive and active controls are currently used with crosswalks across Canada. Passive controls include signs and pavement markings, while active crossings are outfitted with additional overhead signage and pedestrian activated overhead flashers, warning oncoming motorists of the presence of a pedestrian in the crosswalk. Active crossings provide an added level of protection; however, their cost is significant.

The RRFB is an active control that uses rapidly flashing beacons to alert motorists when a pedestrian is crossing. As shown in Figures 1 and 2, RRFBs are typically installed below the side-mounted pedestrian crosswalk signs on both sides of the roadway (and median if present). They use dual rectangular LED lights to display intermittent rapid flashes and they use solar energy for power.

Figure 1: RRFB Treatments

Figure 2: RRFB Device

3. METHODOLOGY

To determine if RRFBs can be effectively used in Calgary, the RRFB Pilot Project involved evaluating yielding compliance before and after RRFB installation. The project also entailed evaluating the performance of the solar power systems used with the RRFBs. The study sites and data collection methodologies are described in following sub-sections.

3.1 Equipment Selection

There are multiple vendors who offer RRFB technology in Canada. The City of Calgary issued a Request for Proposal (RFP) in October 2011 titled, *Pilot Project to Test Solar Powered Rectangular Rapid Flash Beacons*. Four submissions were received and two RRFB systems were purchased from each vendor. The unit price for the RRFB equipment ranged from $3,300 to $5,500. The RRFB vendors are listed in Table 1.

Table 1: Vendors Selected through the RFP Process

Electromega Ltd.
Trafco Canada Ltd.
Fortran Traffic Systems Limited
S & A Supplies Inc.

3.2 Site Selection

RRFBs were installed at eight locations in 2012 and there is one location planned for 2013. The locations allowed for testing with various geometric configurations, roadway cross-sections, and traffic patterns. Table 2 presents characteristics for all locations. The seventh location at which an RRFB was installed in 2012, Quarry Park Boulevard and Quarry Gate SE, is in a developing area and was installed as part of a Development Agreement. Effectiveness of this RRFB will be assessed as the area continues to develop. An eighth RRFB was recently installed at Harvest Hills Boulevard and Harvest Oak Drive North. This location has a very wide centre median and the northbound and southbound lanes have each been considered as a separate installation for study purposes. The ninth installation, to be constructed in 2013, is located at 12 Avenue and 16 Street SW and this location will be used to evaluate augmenting solar power with other power and alarm configurations.

Table 2: Site Characteristics

No.	Location	Facility Type	Traffic Volume	Lanes	Speed (km/h)	Median
1	Glenmore Trail/18 Street SE	Freeway Interchange Loop Ramp	10,208	1	50	-
2	Crowchild Trail/Shaganappi Trail NW	Freeway Interchange Channelized Right Turn Ramp	4,776	1	60	-
3	Sun Valley Boulevard/ Sun Harbour Road SE	Multi-lane Arterial near a recreation area	8,098	5	60	Concrete
4	18 Street/Riverview Close/Riverwood Circle SE	Multi-lane Arterial	14,565	5	50	Concrete
5	Radcliffe Drive/100 Radcliffe Place SE	Collector within School Zone	7,479	2	30	-
6	Douglasdale Boulevard/Douglas Ridge Close SE	Collector within School Zone	6,051	2	30	Boulevard
7	Quarry Park Boulevard and Quarry Gate SE	Collector	N/A	4	50	-
8/NB	Harvest Hills Boulevard /Harvest Oak Drive NB	Multi-lane Arterial	11,306	2 one-way	50	Grassy
8/SB	Harvest Hills Boulevard /Harvest Oak Drive SB	Multi-lane Arterial	8,999	2 one-way	50	Grassy
9	12 Avenue/16 Street SW	Collector	9,411	2 one-way	50	-

3.3 Yielding Compliance

The effectiveness of the RRFBs was evaluated based on before and after yielding compliance using staged crossings. A staged crossing consists of a data collector using the crosswalk in the same manner that a citizen would. The data collector is not identified so motorists are not aware that their behaviour is being studied. The yielding compliance evaluation methodology used is based on procedures published by the Federal Highway Administration (FHWA) in *Effects of Yellow Rectangular Rapid-*

Flashing Beacons on Yielding at Multilane Uncontrolled Crosswalks (Shurbutt & Van Houten, 2010).

For each of the staged crossings, the observer measured the following behaviours:

a. Yielding compliance:
- Noted as yielding if vehicle stopped or slowed to allow pedestrian to cross
- Noted as not yielding if vehicle did not stop, but would have been able to do so safely. The ability to stop safely was determined using threshold distance calculated using the Institute of Transportation Engineers (ITE) signal formula.
- The number of vehicles that did not yield was documented.

b. Yield location was also noted. Yield location is the distance from the crosswalk where the vehicle comes to a complete stop. The increments at which the yield location of each vehicle were recorded are displayed in Table 3.

Table 3: Increments of Yield Location documentation

Yield Location
less than 3 m
more than 3 m but less than 6 m
more than 6 m but less than 10 m
more than 10 m but less than 15 m
more than 15 m but less than 20 m
more than 20 m but less than 30 m
more than 30 m

c. Unsafe behaviours:
- Attempts to pass a stopped/yielding vehicle
- Hard braking behind a stopped/yielding vehicle
- Vehicle/pedestrian conflicts involving evasive action taken by a driver or pedestrian
- Pedestrian trapped at centerline/median.

The staged crossings were conducted as consistently and naturally as possible. The data collector approached the crosswalk with the intent to cross, placing one foot in the crosswalk when the vehicle was beyond the threshold distance. If the driver made no attempt to stop, the pedestrian did not proceed to cross.

At each site, the study was conducted in one direction of travel. The data collection was the same for each site, with 100 or more compliance samples collected during the before period and 100 or more compliance samples collected during the after period. In each instance, the samples were collected during one day, split between morning, lunch and afternoon peak periods.

4. FINDINGS AND DISCUSSION

The findings for yielding compliance, location, unsafe behaviours, and functionality testing are presented in the following sub-sections. RRFB systems from four different manufacturers were used and each had slightly different designs. This may have contributed to the results of the yielding compliance study however this was not assessed as part of the trial.

4.1 Yielding Compliance

As shown in Table 4, the evaluation revealed that the RRFBs increased yielding compliance at seven crosswalks. Motorist yielding increased between 5 and 26 percent, depending on the site, with compliance increasing by an average of 15 percent.

Table 4: Before and After Yielding Compliance

No.	Location	Yielding Percentage Before	Yielding Percentage After	Increase in Yielding
1	Glenmore Trail/ 18 Street SE	81	100	19
2	Crowchild Trail/ Shaganappi Trail NW	77	90	13
3	Sun Valley Boulevard/ Sun Harbour Road SE	87	98	11
4	18 Street/ Riverview Close/Riverwood Circle SE	74	100	26
5	Radcliffe Drive/100 Radcliffe Place SE	84	99	15
6	Douglasdale Boulevard/ Douglas Ridge Close SE	94	99	5
7	Quarry Park Boulevard and Quarry Gate SE	N/A	N/A	N/A
8NB	Harvest Hills Boulevard/ Harvest Oak Drive North Crossing - northbound	87	98	11
8SB	Harvest Hills Boulevard/ Harvest Oak Drive South Crossing - southbound	83	96	13
9	12 Avenue/16 Street SW	N/A	N/A	N/A

Results are graphically represented in Figure 3. The highest increase in yielding compliance occurred at Site 4 (18 Street and Riverview Close SE) followed by Site 1 (Glenmore Trail and 18 Street SE). The school zone sites had a better than average yielding compliance during the before period followed by the ramps and the multi-lane arterial site. Site 3 (Sun Valley Boulevard and Sun Harbour Road SE) also had better than average yielding which could be attributed to the proximity to a recreation area with less visual stimulus surrounding the installation.

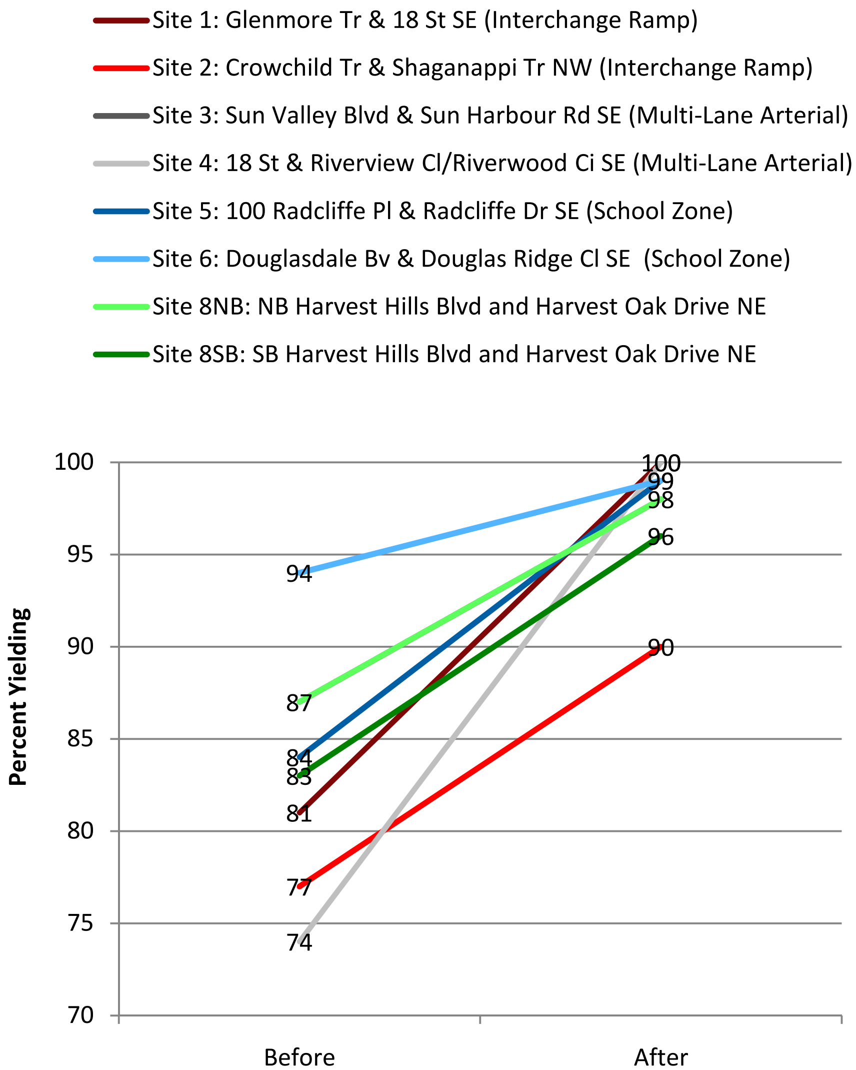

Figure 3: Yielding Compliance Improvements

One location that did not reach close to 100 percent yielding after the installation of the RRFB is Site 2 (Crowchild Trail and Shaganappi Trail NW). The yielding at this location improved for pedestrians crossing eastbound, but there was no improvement for pedestrians crossing westbound. The curvature of the approach along this ramp is likely a contributing factor, as it reduces the intensity of the flasher brightness to an approaching motorist.

4.2 Yield Location

Figure 4 shows the yield location data for all the sites tested.

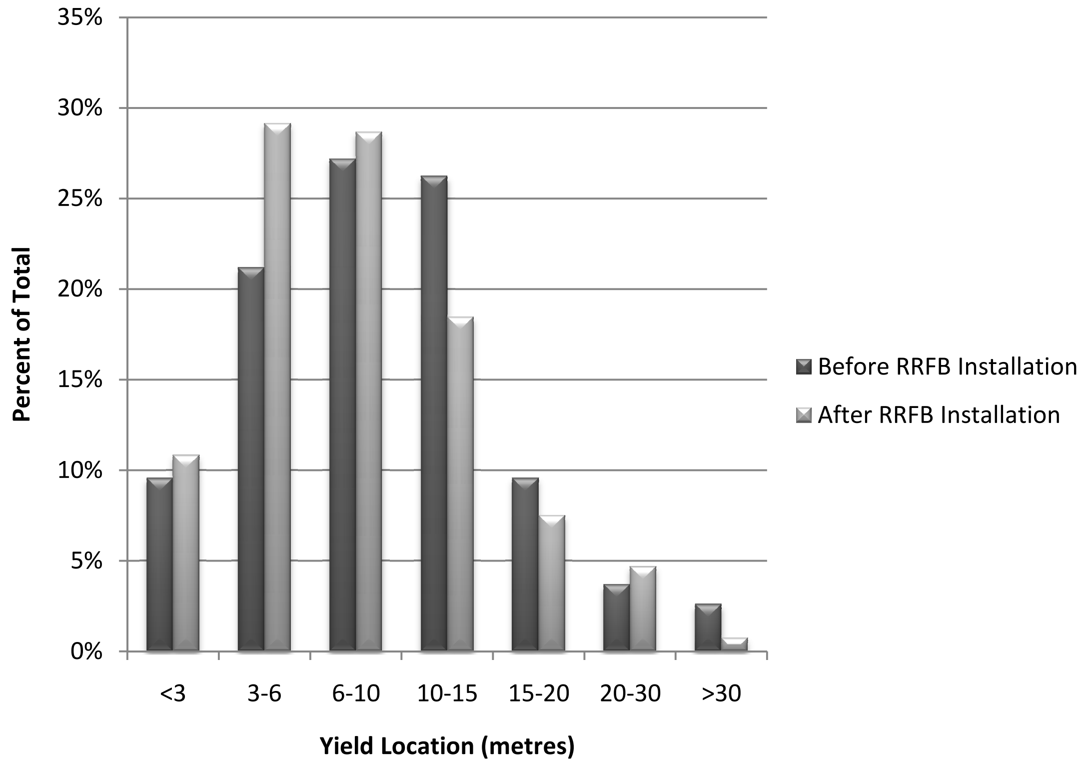

Figure 4: Yield Location Results

An increase in yielding within 10 metres of the crosswalk after the installation of the RRFB was evident for all locations with a single lane approach. This is not likely to pose safety issues in the application of RRFBs, due to the single approach lane. Yield location data for multi-lane approaches (Sites 3, 4, 8NB, and 8SB) showed a decrease in yielding within 10 metres of the crosswalk during the after period. This would increase pedestrian safety, as it reduces the situation on multi-lane approaches where a vehicle stopped in close proximity to the crossing can block the sightlines between a pedestrian and a vehicle in an adjacent lane.

4.3 Unsafe Behaviours

There was one incidence of a vehicle attempting to pass a stopped/yielding vehicle during the before period; there were no such incidences in the after period.

There were several incidences of hard braking behind a stopped/yielding vehicle at three of the eight sites:

- At Glenmore Trail and the 18 Street ramp, two vehicles engaged in hard braking during the before period and four vehicles did so during the after period.
- At Crowchild Trail and the Shaganappi Trail ramp, two vehicles engaged in hard braking during the before period and two vehicles did so during the after period.
- At Sun Valley Boulevard and Sun Harbour Road, three vehicles engaged in hard braking during the before period and none did so during the after period.

However, these results were not statistically significant as the number of occurrences was too low to complete tests.

There were no incidences of conflicts involving evasive action taken by a driver or pedestrian, or instances of pedestrians trapped at centerline/median during data collection.

5 FUNCTIONALITY AND MAINTENANCE

An important component of the RRFB Pilot Project was to assess the functionality of the solar power systems in Calgary's environment. The RRFBs were tested at each location after a period of cold weather (below -20 degrees Celsius). Testing was conducted during daytime and included activating the flasher for 20 cycles. A video of the flashing beacon was taken before and after the 20 flasher activations to assess any visual degradation in intensity and flashing time measurements. The functionality tests did not reveal any major concerns. The RRFB performance and flashing cycle duration were maintained after 20 cycles of flasher activation.

Maintenance and functionality of each installation were monitored. Regular monthly maintenance schedules were performed throughout the winter months and additional trouble calls were documented. Table 5 provides a summary of repairs completed during regular monthly maintenance, as well as the number of service calls the location received throughout the year.

Table 5: Summary of Repairs Performed During Regular Maintenance Schedule and Service Calls

Location	Nov	Dec	Jan	Feb	March	April	#of calls
Glenmore Trail/18 Street SE	🟢	🔴	🟢	🟢	🟢	🟢	**0**
Crowchild Trail/Shaganappi Trail NW	🔴	🟢	🔴	🟢	🟢	🟢	**2**
Sun Valley Boulevard/ Sun Harbour Rd	🟢	🔴	🔴	🟢	🟢	🟢	**0**
18 Street/Riverwood Circle SE	🟢	🔴	🟢	🟢	🟢	🟢	**1**
Radcliffe Drive/100 Radcliffe Place SE	🟢	🔴	🔴	🟢	🟢	🟢	**2**
Douglasdale Blvd/Douglas Ridge Cl SE	🟢	🔴	🔴	🟢	🟢	🟢	**3**
Quarry Park Blvd/ Quarry Gate SE	🟢	🔴	🔴	🟢	🟢	🟢	**0**
Harvest Hills Blvd /Harvest Oak Dr Northbound	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Harvest Hills Blvd /Harvest Oak Dr Southbound							
12 Avenue/16 Street SW	N/A	N/A	N/A	N/A	N/A	N/A	N/A

During winter months, each location required servicing over and above regular monthly maintenance. In each case, field crews had to clear snow off the solar panels and ensure each unit's battery was able to charge. Two of the units required repairs from water damage. Two units experienced difficulty with the push buttons, causing them to be non-operational.

All issues reported for each location throughout the year are summarized in the tables below. The issues related to the regular monthly maintenance are highlighted in orange and the incidents related to Service Requests by citizens are in white.

Table 6: Glenmore Trail/18 Street SE

06/12/2012	Not functioning - snow covered solar panels

Table 7: Crowchild Trail/Shaganappi Trail NW

07/11/2012	Unit not working/water in heads/had to seal heads
14/01/2013	Unit not working/removed snow /now charging
19/06/2012	Main fuse board blown and new fuse board blown
20/11/2012	Not functioning - water in apparatus

Table 8: Sun Valley Boulevard/Sun Harbour Road SE

06/12/2012	Not functioning - snow covered solar panels
14/01/2013	Unit not working/removed snow /now charging

Table 9: 18 Street/Riverview Close/Riverwood Circle SE

05/12/2012	Snow covered solar panels/ push button not working
16/01/2013	Median pole strobe not functioning

Table 10: Radcliffe Drive/100 Radcliffe Place SE

05/12/2012	Snow covered solar panels/removed snow /now charging
14/01/2013	Snow covered solar panels/removed snow /now charging
20/11/2012	Flashers stuck on
30/11/2012	Pole cover missing

Table 11: Douglasdale Boulevard/Douglas Ridge Close SE

05/12/2012	Not functioning - water in apparatus
14/01/2013	Unit not working/removed snow /now charging
19/06/2012	Replaced circuit board
26/06/2012	Flashers stuck on
18/07/2012	Not functioning/ trouble shooting with manufacturer

Table 12: Quarry Park Blvd/ Quarry Gate SE

05/12/2012	snow covered solar panels/removed snow /now charging
14/01/2013	snow covered solar panels/removed snow /now charging

Maintenance crews report that there is generally a low level of reporting of issues at pedestrian crossing devices. Therefore, using trouble calls as a measure of issues at the RRFB locations may not be representative of actual issues. Recognizing that this also applies to traditional overhead flashing beacons, it is still worth noting that there were only 11 trouble calls in 2012 to the 250 traditional overhead flashing beacon systems in the city.

For a pedestrian crossing device to be considered a safe traffic control, it must be reliable. Through the regular maintenance of these systems, in addition to trouble calls received, it has been shown that solar power is not a reliable sole source of power. To increase the reliability to an appropriate level, alternatives to solar power must be investigated.

Several agencies that have used solar powered devices have been contacted to determine their experience. The Calgary Parking Authority has a large number of solar powered Park Plus machines and they have indicated that a regular maintenance program is required during winter months to support operation of the devices. The City of Edmonton has a large number of solar powered portable message boards mounted on trailers. They have had issues with snow collecting on solar panels, batteries failing to charge as a result and the devices being non-operational. The City of Calgary has had similar issues with the solar powered portable message boards mounted on trailers. A regular maintenance program, including clearing snow from solar panels after snow events, is needed to support reliable operation of these devices. Without regular maintenance, issues can arise. Other agencies with a small number of devices (University of Calgary, Calgary International Airport) have indicated that they have used solar powered devices with very few issues.

Although it was not a goal of the RRFB Pilot Project to specifically compare products from different vendors, the project has shown that there are features of some of the systems that are desirable and should be considered when RRFBs are purchased in the future. These include:

- Solar panels that can be installed at adjustable angles. This permits installing the panels to reduce the likelihood of snow accumulation, whereas solar panels that are at fixed angles do not permit this.
- Beacons that have adjustable brightness. This permits adjusting the beacons for different installation circumstances.
- Robust battery systems. The more robust batteries are, the less likely it is that failures will occur.

6. COSTS

The equipment, installation, maintenance, and cost to connect to continuous power for each of the six RRFB locations are shown in Table 13. The cost to connect to power is estimation and is subject to change.

Table 13: Annual Capital and Maintenance Cost of each RRFB Location

Location	Equipment Cost ($)	Installation Cost ($)	Total Cost ($)	Maintenance Cost ($)	Est. Cost Connect to Power ($)
Glenmore Trail/18 Street SE	11,000	9,800	**20,800**	1,800	13,700
Crowchild Trail/Shaganappi Trail NW	8,600	6,300	**14,900**	2,100	10,700
Sun Valley Boulevard/Sun Harbour Road	9,900	3,300	**13,200**	1,980	22,500
18 Street/Riverwood Circle SE	16,500	23,000	**39,500**	2,100	18,500
cliffe Drive/100 Radcliffe Place SE	11,000	9,000	**20,000**	2,400	16,400
Douglasdale Blvd/Douglas Ridge Close SE	12,900	7,600	**20,500**	2,970	14,000
Quarry Park Blvd/ Quarry Gate SE	9,900	3,600	**13,500**	1,400	18,500
Harvest Hills Blvd /Harvest Oak Dr Northbound	22,000	24,000	**46,000**	N/A	20,000
Harvest Hills Blvd /Harvest Oak Dr Southbound					
12 Avenue/16 Street SW	11,000	N/A	**N/A**	N/A	N/A

The long term reliability and the ongoing maintenance and life-cycle costs of the batteries will require additional investigation before a solar power only device program is implemented.

The approximate cost to install a traditional pedestrian-activated overhead flasher system with a continuous power supply is $70,000 to $95,000. The cost to install an RRFB is approximately $15,000 to $40,000. The cost to connect an RRFB to a continuous power supply is approximately $10,000 to $25, 000. The site specific total costs to connect the trial RRFB to continuous power were estimated at $25,000 to $66,000.

7. FUTURE STUDIES

The RRFB Pilot Project has indicated the need to complete the following:

- Investigate alternatives for power to address solar power concerns.

- Conduct a solar power reliability study.
- Investigate yielding behaviour at traditional overhead beacons vs. yielding at RRFBs.
- Investigate yielding at a location before and after installation of traditional overhead beacons.
- Develop standards and guidelines for implementation of RRFB devices.
- Conduct a technology review with vendors who have RRFB devices.

7.1 Retro-fitting options

To ensure RRFB's are reliable and therefore a safe method of traffic control, solar power cannot be the sole power source for RRFBs. Alternative power sources under investigation are shown in Table 14.

Table 14: Retro-fitting Options

Option 1	Connecting to Permanent AC Power This option eliminates the need for battery maintenance, which historically has been the most significant negative aspect to solar power devices. Batteries require regular monthly maintenance and have a relatively short life cycle. The approximate cost to provide power to the existing and future units would be $10,000 – $25, 000, variable depending on location.
Option 2	Connecting to Streetlight Power This option uses streetlight power to supplement the solar power used to recharge batteries. As streetlights are only powered at night, this recharging will occur overnight. There are challenges with connecting to streetlight power, including conforming to the Canadian Electrical Code and existing capacity constraints. Further investigation will be conducted to determine the feasibility of connecting to streetlight power. This solution may only be feasible at specific locations.
Option 3	Retrofitting with Automatic Alarms This option involves installing a device that triggers delivery of an email to the maintenance team if an RRFB's battery voltage is low. This device would decrease maintenance response times and would increase the device reliability by ensuring shorter and fewer disruptions to their function. There would be an added costs associated with device installation as well as possible increases in maintenance costs. However, the maintenance costs would reflect actual needs as opposed to needs determined from complaints or monthly checks.

Option 1, connecting to permanent AC power, is recommended for all existing RRFBs. The estimated cost to do so is $135,000.00. Options 2 and 3 will be investigated.

7.2 Yielding at Traditional Beacons vs. Yielding at RRFBs

RRFB testing by the US Federal Highway Administration indicated that RRFBs at pedestrian crosswalks are dramatically more effective at increasing driver yielding rates to pedestrians than traditional overhead beacons. However, yielding patterns in the United States may be different from those in Canada. Field studies to compare the yielding rates at overhead beacons in comparison to RRFB yielding rates will be conducted during the summer of 2013.

7.3 Transportation Association of Canada (TAC) Project

A TAC project titled, *Rectangular Rapid Flashing Beacons Guidelines,* has been approved by the Transportation Association of Canada and the City of Calgary has taken the lead on the project. The objectives of the project are to:

- develop technical specifications, such as brightness and battery specifications,
- develop implementation guidelines, such as site selection criteria and site design criteria, and
- recommend TAC update the Manual of Uniform Traffic Control Devices to include RRFBs.

The project is planned to be completed by the spring of 2014.

Excepting one further RRFB installation that will take place at the intersection of 12 Avenue and 16 Street SW this year, which is intended to be used as a test site for connection of an RRFB to street light power, The City of Calgary does not plan to install additional RRFB devices until the TAC project is completed.

8. PUBLIC ENGAGEMENT

Table 15 summarizes the public engagement that was conducted for the RRFB Pilot Project.

Table 15: Public Engagement Strategy

Webpage	A Webpage was created at the beginning of the Pilot Project to inform citizens of the locations of installations and when the devices would be constructed. It included information about RRFBs and a FAQ sheet.
Community Association	Each Community Association was contacted by phone and email regarding the request from each community for feedback about the RRFBs. A one page PDF was provided to Community Association representatives for distribution. Each Association shared the request for feedback through their own networks.
Message Boards	Message Boards were placed at each RRFB location for one week, requesting citizens to call 311 to provide feedback on the RRFBs.

8.1 Feedback

There were 40 opinions received regarding the RRFB locations. The distribution of opinions is displayed in Figure 5.

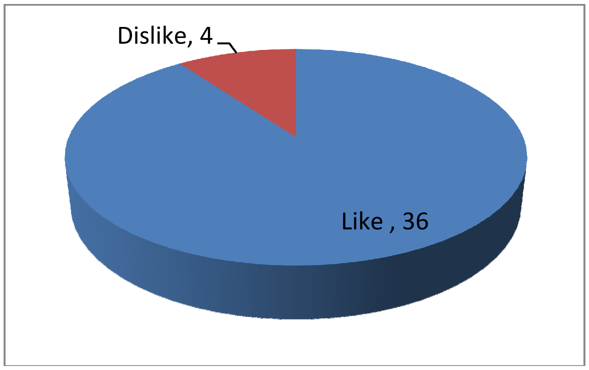

Figure 5: Distribution of Opinions

Those who disliked the RRFBs indicated their reasons were as follows:

- The beacons were located too low on the sign poles
- The beacons were not bright enough, and
- The batteries were not reliable.

9. CONCLUSIONS AND RECOMMENDATIONS

The installation of RRFBs improved yielding compliance. Solar power is unreliable and should not be the sole power source used for RRFBs. The approximate cost to install a traditional pedestrian-activated overhead flasher system with a continuous power supply is $70,000 to $95,000. The cost to install an RRFB is approximately $15,000 to $40,000. The cost to connect a RRFB to a continuous power supply is approximately $10,000 to $25, 000. The site specific total costs to connect the trial RRFB to continuous power were estimated at $25,000 to $66,000.

To ensure the reliability of the RRFBs currently in place, the existing devices will be connected to continuous power. The estimated cost to do so is $135,000.00 for all existing locations. RRFBs should be incorporated into The City of Calgary's toolbox of pedestrian treatments when equipment reliability issues are resolved and guidelines for their use, currently being developed by the Transportation Association of Canada, are completed.

REFERENCES

Shurbutt, J.; & Van Houten, R. (2010). *Effects of Yellow Rectangular Rapid-Flashing Beacons on Yielding at Multilane Uncontrolled Crosswalks.* McLean, VA: Federal Highway Administration. Retrieved from http://www.fhwa.dot.gov/publications/research/safety/pedbike/10043/10043.pdf