Transportation Association of Canada

Recommended Practices for LED-Embedded Traffic Signs (LETS)

December 2011

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ISBN 978-1-55187-318-4

Photos: Stop sign, Alberta Transportation, photo editing - Gerry Forbes
Yield sign, http://www.freeimages-photos.com, photo editing - Gerry Forbes

TAC REPORT DOCUMENTATION FORM

Title and Subtitle

Recommended Practices for LED-Embedded Traffic Signs (LETS)

Report Date	Coordinating Agency and Address	ITRD No.
December 2011	Transportation Association of Canada 2323 St. Laurent Boulevard Ottawa, ON K1G 4J8	

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Abstract

This document provides guidelines for use of LED-embedded static traffic signs (LETS) on Canadian roads. The conspicuity of a static traffic sign may be increased by embedding light emitting diodes (LEDs) on the sign face. LEDs on the sign face may also serve to increase the legibility distance of the sign by highlighting the sign message or the outline of a uniquely shaped static sign. Due to the potential for LED-embedded traffic signs to be distracting, and because excessive use may decrease the effectiveness of similar static signs, LED-embedded traffic signs use should be limited.
To take advantage of the shape-recognition advantage provided by LETS, LETS should be restricted to STOP signs, YIELD signs, and the stop side of the STOP/SLOW paddle as these are uniquely shaped signs and are most easily recognized from shape alone.

The document is intended as a reference for traffic engineering practitioners and supplements the *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC), which is the primary reference document for practitioners concerning traffic control devices design and use.

Keywords

Traffic Control
Attention
Driver
Flashing Light
Improvement
Light Emitting Diode
Specifications
Traffic sign
Visibility
Visibility distance

Supplementary Information

The *Knowledge Base for Recommended Practices for LED-Embedded Traffic Signs* is available through the TAC online library catalogue.

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Acknowledgements

The *Recommended Practices for LED-Embedded Traffic Signs* report was developed with funding provided by several agencies. TAC gratefully acknowledges the following partners for their contributions to the project:

Alberta Transportation

City of Edmonton

International Municipal Signal Association

Manitoba Infrastructure and Transportation

Ville de Montréal

New Brunswick Department of Transportation

Ontario Ministry of Transportation

City of Ottawa

Ministère des transports du Québec

Saskatchewan Ministry of Highways and Infrastructure

Transport Canada

City of Vancouver

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This report was developed under the supervision of a project steering committee of volunteer members. The participation of committee members throughout the project is gratefully acknowledged.

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James Keefe
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Don MacDonald
City of Edmonton

Brian McKinney
New Brunswick Department of Transportation

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City of Ottawa

Simon Trépanier
Ministère des transports du Québec

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Executive Summary

Embedding Light Emitting Diodes (LEDs) in the face of a traffic sign is one of many possible strategies to increase the conspicuity of a traffic sign. The primary objective of LED-embedded traffic signs (LETS) is to increase the conspicuity of a static sign through the use of flashing LEDs embedded in the sign face. When the LEDs are used to highlight the border of a uniquely shaped sign, LETS can also increase legibility distance during conditions of low light. While increased conspicuity and legibility distance over static signs is a desirable advantage, there is a potential for LETS to be distracting, and to decrease the effectiveness of similar static signs. To minimize the negative impacts of LETS, LETS use should be limited.

To take advantage of the shape-recognition advantage provided by LETS, LETS should be restricted to STOP signs, YIELD signs, and the stop side of the STOP/SLOW paddle as these are uniquely shaped signs and are most easily recognized from shape alone. LETS may be used in place of static signs at locations where a sign is not expected or where driver attention is not directed toward a critical sign. The ability of LETS to capture driver attention is severely diminished if LETS are in wide-spread use within a jurisdiction. It is essential that the use of LETS be strictly managed through sound engineering and rational decision-making.

1 Introduction

Scope

This document provides guidelines for LED-embedded traffic signs (LETS) on Canadian roads. LETS are static traffic signs that have been embellished by embedding light emitting diodes (LEDs) in the sign face, and are distinguished from variable message signs and radar message boards that use LEDs to increase the conspicuity of an existing sign. Variable message signs use LEDs to convey the entire message, while LETS are used to highlight an existing message. LETS are also different from internally illuminated or backlit traffic signs.

The guideline covers LETS use, design and operation and sets out mandatory (shall/must/ will), and optional (should/may/can) requirements.

These guidelines supplement the *Manual of Uniform Traffic Control Devices for Canada* (MUTCDC), the primary reference document for practitioners concerning design and use of traffic control devices.

The topics outlined in this guideline include:

- *Warrants for use*
- *Permitted LED colours*
- *Number and placement of LEDs*
- *Intensity or brightness of LEDs*
- *Flashing mode (e.g., simultaneous flash, wig-wag or alternating flash, etc.)*
- *Flash rate (i.e., number of flashes per second)*
- *Other considerations*
- *Operations (i.e., constant flash, or time-of-day/traffic actuated)*

Use of This Document

The purpose of this document is to advance practice guidelines for LETS use on Canadian roads. This document has been developed primarily as a reference for traffic engineering practitioners with the responsibility for selecting and implementing traffic control devices.

Strenuous efforts have been made to provide accurate, up-to-date and full coverage of the issues relating to LETS use in Canada. These guidelines have largely been developed according to accepted human factors principles, and “good practice” as defined by wide-spread use of guidelines across a variety of Canadian jurisdictions.

When possible the documented practices provide quantitative guidance for the use and placement LETS. There is also a reasonable amount of qualitative advice and engineering judgement that must be used as needed for the given situation and jurisdiction.

2 Warrants for Use

The primary objective of LED-embedded traffic signs (LETS) is to ***increase the conspicuity*** of a static sign through the use of flashing LEDs embedded in the sign face. When the LEDs are used to highlight either the border of a uniquely shaped sign or the pictogram/legend of the sign, LETS can also ***increase legibility distance during conditions of low light***. While increased conspicuity and legibility distance over static signs is a desirable advantage, there is a potential for LETS to be distracting, and to decrease the effectiveness of similar static signs. To minimize the negative impacts of LETS, **LETS use should be limited**.

To take advantage of the shape-recognition advantage provided by LETS, LETS should be ***restricted to STOP signs, YIELD signs, and the stop side of the STOP/SLOW paddle*** as these are uniquely shaped signs and are most easily recognized from shape alone.

It is recognized that certain symbols and pictograms (e.g., chevrons) are unique shapes, and LED-pixelated versions of these images may also be identifiable at a glance. However, given that LETS use is unproven in reducing crash risk, and the experience with LETS is mainly limited to STOP signs, at this time it is advisable to limit their use to STOP and YIELD signs.

LETS are also better than improvements in sheeting or larger signs when it comes to increasing detection – particularly *attention conspicuity* where drivers are not actively searching for the signs. This is in large part due to the blinking of the LEDs and in that regard they may be no better than, but at least as good as, flashing beacons mounted over the sign. Therefore, in instances where sign conspicuity is insufficient, because a sign is unexpected and the driver is not actively searching for the sign, then LETS and flashing beacons are favoured over other conspicuity-enhancing techniques.

LETS may be used in place of static signs at locations where a sign is not expected or where driver attention is not directed toward a critical sign. Examples include:

- Locations with sign visibility limitations (horizontal curves, dusk/dawn glare, etc.);
- Locations with documented problems of drivers failing to recognize an intersection;
- Expectancy violation; and
- Crash record resulting from failure to observe a traffic control device.

Cautious Use

One of the reasons that LETS are effective in capturing driver attention is that they are used sparingly. This means that they are an anomaly in the usual visual scene, and as such stand out against the visual noise. The ability of LETS to capture driver attention is severely diminished if LETS are in wide-spread use within a jurisdiction. It is essential that the use of LETS be ***strictly managed*** through sound engineering and rational decision-making.

Moreover, embedding LEDs in the face of a standard sign is an enhancement, and one that if used widely may diminish the effects of the standard sign. To maintain the integrity of LETS ability to command attention, and to ensure that LETS do not reduce the effectiveness of static signs in attracting attention, LETS shall be used sparingly.

The ability of LETS to command attention may also distract drivers' attention from another sign or condition. LETS shall not be used in situations where the device becomes a significant distraction for motorists.

Consider all Options

Embedding LEDs in the face of a traffic sign is one of many possible strategies to increase the conspicuity of a traffic sign. Other available and commonly used strategies on the approaches to unsignalized intersections are:

- *Reposition the sign*
- *Increase the size of the sign*
- *Provide a more reflective sign sheeting*
- *Post an additional (left-side mounted) sign*
- *Post a STOP AHEAD warning sign*
- *Add "STOP AHEAD" pavement markings*
- *Add transverse rumble strips*
- *Add a flashing beacon*

If the conspicuity of a sign is insufficient for the condition, which usually manifests itself in an increased collision risk, then any one of the above methods or embedding LEDs in the sign face are available options. The preferred response to this situation is to employ one of the available methods, and assess whether the issue has been resolved. If the issue is unresolved then another solution is employed and the assessment is conducted again. This iterative approach is repeated until the issue is resolved. In determining the order of selection for the techniques, the following principles should be applied:

1. ***The technique should be selected to suit the purpose.***
   For example, if a conspicuity problem exists at all times of the day, employing more reflective sign sheeting is not generally suitable as it only addresses night-time issues. Alternatively, if the concern seems to be attention conspicuity, (i.e., not actively looking for a sign) a flashing beacon or LETS may be preferable.

2. ***Review the available evidence on technique effectiveness***
   The state-of-knowledge on any particular device or technique is constantly evolving, and the practitioner should be aware of the most up-to-date information to make informed decisions.

3. ***Conform to local policies***
   If an established policy or practice is used within a jurisdiction, then conformance to that practice is an important step in meeting driver expectations.

4. ***Select the technique with the minimum environmental impact***
   All of the available options tend to have minimal impacts. However, Dark-Sky policies that strive to preserve and protect the night-time environment through environmentally responsible outdoor lighting may be a consideration.

5. ***The lowest cost option***
   Both capital and operating costs of the selected option should be a factor in selecting the treatment.

It should also be noted that adding a flashing beacon or replacing a static sign with a LETS are techniques that will be distinct and noticeable to the motorist. These two techniques have the greatest potential to reduce the effectiveness of static signs. Therefore, these two options for increasing conspicuity should be the last option, unless the conditions of the situation dictate otherwise.

Since LETS are intended for use as STOP or YIELD sign enhancements, and are one of many available options to increase sign conspicuity, the following is offered as a general guideline for use.

The conspicuity of a STOP/YIELD sign may be increased through one or more of the available measures when any one of the following conditions presents:

- A high frequency of crashes that result from a failure to recognize the STOP/YIELD sign (e.g., two or more reportable crashes per year over a period of three years, or if a longer review period is desired three or more crashes per year over a period of five years);
- A high incidence of STOP sign violations that result from a motorist failing to notice the STOP sign, or noticing the STOP sign too late;
- The approach to an intersection where the speed limit on either of the intersecting roads is 90 km/h or more and failure to recognize the intersection control may result in a high severity crash;
- A visually complex environment where the STOP or YIELD sign is not easily detected, or other components of the visual scene are competing for the drivers' attention; or
- A challenging intersection approach that diverts from intersection control to other aspects of the driving task.

If any one of the above conditions is satisfied, the practitioner should consider implementing measures in the following order starting from Item A:

A. Increase the size of the sign
B. Provide a more reflective sign sheeting
C. Post an additional (left-side mounted) sign
D. Post a STOP AHEAD warning sign
E. Add "STOP AHEAD" pavement markings
F. Add transverse rumble strips
G. Add a flashing beacon
H. Embed LEDs in the border of the sign

If the visibility of a sign on the approach to the intersection is less than the stopping sight distance, and the visibility obstruction cannot be removed, measures A and B should not be considered. Similarly, measure C may not be effective unless the left-side placement is such that it is visible from a point upstream that affords stopping sight distance. If the sign is not visible sufficiently far upstream, measures G and H will also have short visibility distances but due to the flashing operation, they may improve driver performance. These measures are generally poor choices for a limited visibility condition.

Measure B should be limited to high crash frequencies or high incidences of stop sign violations when these conditions occur during hours of darkness.

Measure F should not be used in urban areas or areas where the noise created by the rumble strips will create a disturbance for nearby residents. Further guidance on transverse rumble strips is available in *Best Practice Guidelines for the Design and Application of Transverse Rumble Strips [TAC, 2005]*.

Measures D, E, and F involve the placement of items upstream of the intersection and should only be used if there is not another intersection or major driveway located in between the subject intersection and the upstream measure. Also, these measures should be sufficiently far downstream of the last intersection encountered by the motorist so that the driver is not likely to miss the measure because of diverted attention. For this last purpose, it is suggested that these measures be at least 3 seconds downstream of the last intersection at the posted speed limit.

Measures F, G, and H should only be used on approaches where the traffic is 500 vehicles per day or more. Additionally, as these measures have the potential to reduce the effectiveness of static signs, these measures should not be tried until all of the static signs and markings measures have been ruled out, or been tried and found unsuccessful.

Measures G and H shall not be used on the same approach. The principle advantage of either measure is the flashing lights associated with each system. Installation of either flashing light system should be sufficient to attract driver attention. There is a real concern that employing both methods at one location will start an increasing spiral of lighting which is successively more attention-getting as different arrangements of devices strive to be more conspicuous than the previous. This spiral will erode the effectiveness of the static sign in attracting the attention of motorists.

3 Flash Rate

LETS installations should use a flash rate of 50 or 60 flashes per minute (according to local policy), and ***may*** be increased up to 120 flashes per minute if an engineering study indicates that the initial flash rate is not providing the intended effect either in terms of sign detection times, or driver reaction times. Conspicuity increases and detection times decrease as flash rates increase, so in instances where a LETS with a flash rate of 60 flashes per minute is still going unnoticed, it may be beneficial to increase the flash rate up to 120 flashes per minute. Similarly, a faster flash rate implies a greater sense of urgency, so in limited visibility conditions where a quick reaction is required, a 90 or 120 flash rate may be more appropriate.

If LETS are operated in a traffic-actuated mode, the flash rate may also vary according to the guideline in Section 9.

LETS shall not be flashed between the rates of 5 flashes per second and 30 flashes per second, as these frequencies can trigger epileptic seizures.

4 Flash Pattern

As the LEDs embedded in the sign face highlight the sign shape, the LEDs shall flash simultaneously. Additionally, if two similar signs at a site are enhanced with LEDs (e.g., right and left side mounted STOP signs), both signs shall also be synchronized to flash at the same time and rate.

5 LED Colour

Following the fundamental principle that the LEDs are intended to highlight the shape of the STOP or YIELD sign, and the dominant colour of these signs are red, the LEDs placed on these sign borders shall be red.

The chromaticity (colour regions) for the red LEDs shall be in accordance with the 1931 Commission internationale de l'éclairage (CIE) colour space (or chromaticity diagram) as follows:

Table 1: Chromaticity Coordinates for LED Colour
(Based on 1931 CIE Chromaticity Diagram)

Colour	Point	x	y
Red	1	0.692	0.308
	2	0.681	0.308
	3	0.700	0.290
	4	0.710	0.290

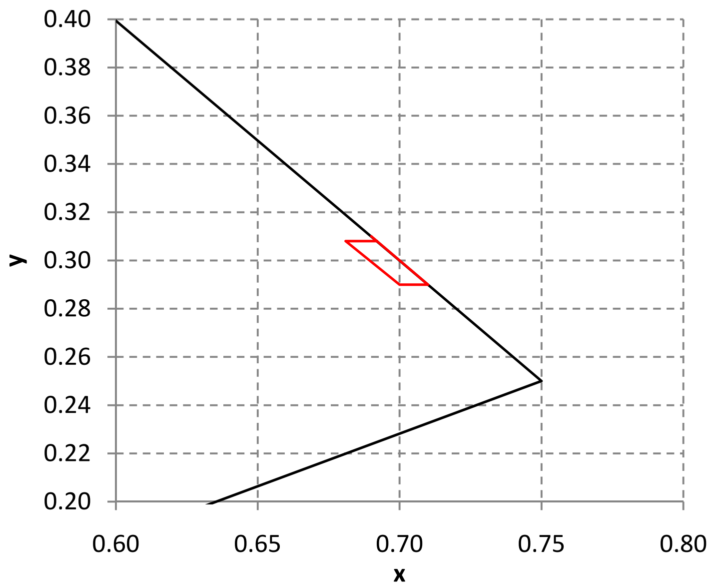

Figure 1: Chromaticity Diagram Showing LETS Colours

The colour of all pixels should be uniform across the display. As a general guideline, the dominant wavelength for any individual colour measurement should be within 3 nm of the dominant wavelength for the average colour measurement of all LEDs in the sign face.

6 LED Number and Placement

When the LEDs are energized they are a pixelated or bitmap image of the sign outline/shape. The goal is to provide enough LEDs at an adequate spacing so that the road user can identify shape being portrayed by the LED display without causing disability glare or creating a display that is distracting.

The shape displayed by the LEDs may be a series of individual LEDs or several clusters of closely-spaced LEDs that appear to be a single point of light to the observer. Whether individual or clusters of LEDs are used, each point of light is termed a ***pixel***. The centre-to-centre spacing between pixels is called the ***pitch***. The pixel diameter, as the name suggests, is the width of the pixel. However, the light from the LEDs have a halation effect[1], and the effective pixel width is larger than the pixel width.

The number and placement of pixels shall present a reasonable likeness of the static sign shape. The pixel diameter on LETS should be 5 to 10 mm, with smaller pixel diameters generally used on smaller sign sizes. It is permissible to cluster more than one LED to form a single pixel. The pixels shall be placed only on the border of the sign, and the pixel spacing shall be a maximum of 8% of the sign size. The selected pixel spacing shall be used to determine the minimum number of pixels for each sign. An example of a 760 mm STOP and YIELD sign enhanced with LEDs is shown in Figure 2. All pixels shall be evenly spaced.

The maximum pixel pitch for standard size STOP and YIELD signs are shown in Table 2.

Table 2: Pixel Spacing for Standard Size STOP and YIELD Signs

Sign Size (mm)	Maximum Pixel Pitch (mm)
450	36
600	48
760	61
900	72

[1] A halo-like effect resulting from extreme contrast between adjacent illuminated and non-illuminated portions of a sign. The light appears to spread or bleed across the non-illuminated area, making the light source appear larger.

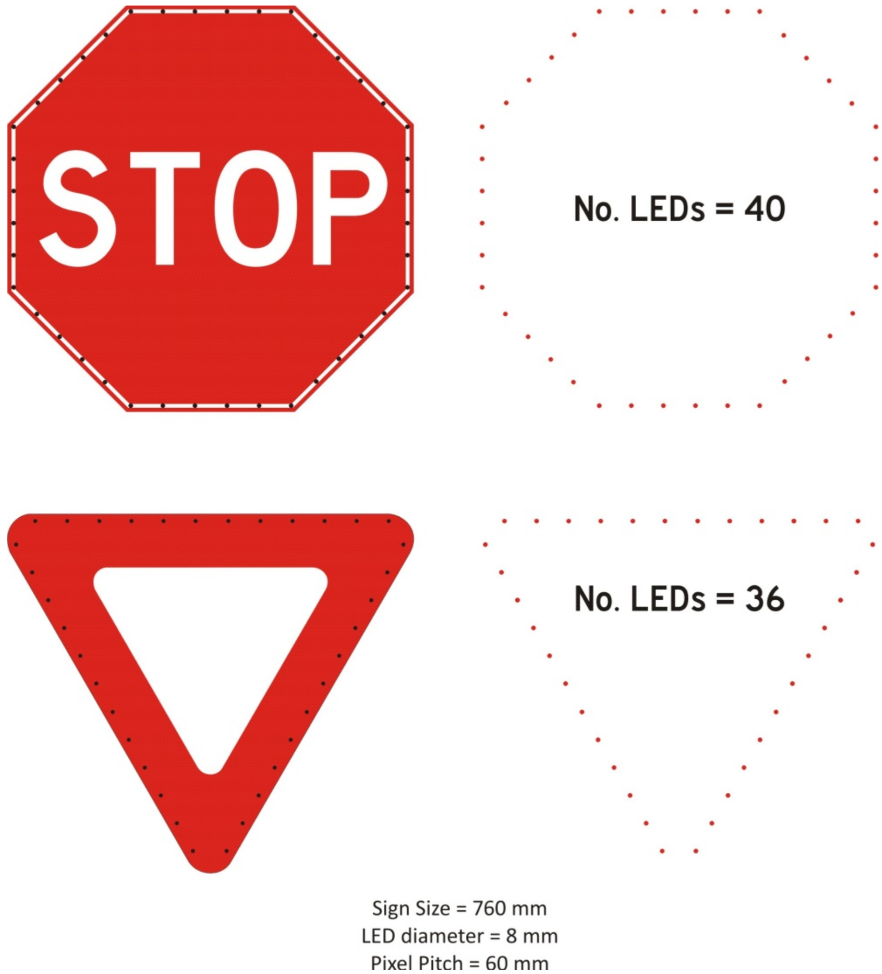

Figure 2: Example Pixel Placement and Spacing

7 LED Intensity

The intensity or brightness of LETS must create enough external luminance contrast such that the sign is bright enough to be conspicuous from the surroundings, and be limited in brightness so as to avoid causing disability glare.

The intensity of the light emitted from an LED is generally described by two elements: the on-axis luminous intensity (the brightness of the LED when looking straight at it), and the spatial radiation pattern (the brightness when viewing the LED at different angles). LEDs are designed to produce light in a narrow beam, so that the light looks brightest when viewed from straight on. As the observer moves away from the axis on the beam, the intensity drops off. The viewing angle of the LED is the off-axis angle where the intensity of the light is 50% of the on-axis intensity.

LED light output is described by several sign manufacturers with terms such as "super-bright," and "ultra-bright". These terms are entirely subjective.

The minimum maintained luminous intensity of the LEDs should be in accordance with industry practice to ensure adequate external luminance contrast. The off-axis intensity should also be in accordance with industry practice to ensure adequate visibility of the LEDs on the approach to the LETS. All LEDs in an installation shall have the same viewing angle. The maximum luminous intensity shall be no more than 5 times the minimum maintained luminous intensity, and shall not create disability glare, reduce sign legibility, or create an undue distraction for motorists.

LETS that operate under different ambient light conditions should incorporate a photo-sensor to adjust the intensity of the LEDs according to ambient light. Alternatively, LETS that flash continuously through the day may be equipped with a clock and controller that automatically dims the light during conditions of low ambient light to reduce glare and distraction effects.

The ratio of the maximum and minimum luminance intensities in a single installation shall be a maximum of 5 to 1.

The effectiveness of LETS is partly related to LED intensity. Since LED intensity decays over time, regular field inspections of installations by qualified personnel should be conducted to ensure that luminance levels and background contrast remain satisfactory.

8 Other Considerations

Sign Placement

LEDs should only be used on signs that are posted in their usual locations as prescribed by the MUTCDC or local policy. It is perilous to employ a LETS at any placement that is not typical because it may confuse motorists' point of reference under night time conditions and lead to crashes. Also, due to LED viewing angles, a driver is not able to see the LEDs for the last 20 to 30 metres, before passing the LETS. This needs to be taken into consideration if LETS visibility/legibility is at issue.

Enforcement

It should be noted that LED enhancements may not be a replacement for a flashing red beacon at an intersection because of the legal meaning attached to the beacon. A flashing red beacon is associated with a legal obligation to halt your vehicle. The flashing red LEDs representing the octagonal shape of a STOP sign has no such meaning. In the instance that a flashing beacon is being used to articulate a regulatory requirement to stop, a LETS is not an adequate substitute.

Finally, it is noted that in some jurisdictions in Canada the dimensions and appearance of STOP and YIELD signs are regulated, such that embedding LEDs in the face of a STOP sign or YIELD sign may render them "unofficial" signs, and not enforceable. The practitioner should ascertain the legal/enforcement ramifications of using LETS and the necessary legislative amendments required (if any) before employing LETS.

Power Failures

When the power supply for a LETS malfunctions or fails the effectiveness of the flashing LEDs is lost. For this reason, regular field inspections of the power source and the ancillary equipment by qualified personnel are recommended.

Sign Reflectivity

The profession has not come to a consensus on the required sign sheeting or the minimum level of retroreflectivity required on LETS. Nonetheless, LETS is generally a measure that is implemented after other methods of increasing sign conspicuity have been tried and found unsuccessful. This means that static signs being replaced with LETS typically employ a minimum of Type III sheeting. Therefore, the minimum level of retroreflectivity for the base sign on a LETS installation should be the same or higher than that used on the static sign that was in place before LETS installation. This ensures that during power failures, and at other times when the sign is dark, the sign will be at least as conspicuous as pre-LETS installation.

9 Operation

LETS may operate at all times, but are generally more effective if they are time-limited and/or traffic actuated.

Time-limited operation will ordinarily have the LEDs flashing continuously during times of darkness. The flashing operation may be triggered by either a photo-sensor, or be pre-programmed using the clock. In any case, the following time-limited operation is recommended:

- *The LETS shall be dark and shall initiate operation only upon a triggering event,*
- *The LETS shall cease operation at a predetermined time after the actuation or in the case of detection, after actuation ends.*
- *All LETS associated with a single installation shall commence and cease operation simultaneously.*

A further enhancement of LETS is to make the installation traffic-actuated. A jurisdiction may use traffic actuation on a continuous flashing LETS, or a time-limited and will likely employ traffic actuation for one or more of the following reasons:

- Conserve power;
- Comply with Dark Sky policies;
- Minimize light intrusion on neighbouring properties;
- Increase the credibility of LETS by flashing only when required; or
- Decrease the negative impacts of LETS on static sign effectiveness.

In the instance that a LETS is traffic-actuated, a detector is required upstream of the stopline to identify vehicles approaching the intersection. If the detector is capable of sensing only the presence of a vehicle at a point on the road, then the detector placement and flash time should be as follows:

$$D = \frac{V^2}{2a}$$

Where: D = Distance from stopline to the detector (metres)
V = Posted speed limit of the approach (km/h)
a = Comfortable deceleration rate (12.3 km/h/s)

$$t = \frac{V}{a}$$

Where: t = Duration of flashing operation (seconds)

V = Posted speed limit of the approach (km/h)
a = Comfortable deceleration rate (12.3 km/h/s)

If the detector is capable of sensing the presence of a vehicle and the vehicle speed, the placement of the detector should be as above, but it may be advantageous to employ a different flash rate depending on the recorded speed. The research has shown that a faster flash rate conveys a greater sense of urgency to the road user, and therefore using a faster flash rate when approach speeds are higher may assist in capturing driver attention and conveying the need to rapidly decelerate. The following guideline is suggested:

Measured Speed Minus Posted Speed (km/h)	Flash Rate (flashes/sec)
< 20	60
21 < V < 35	90
V > 36	120