DMD & Associates Ltd.

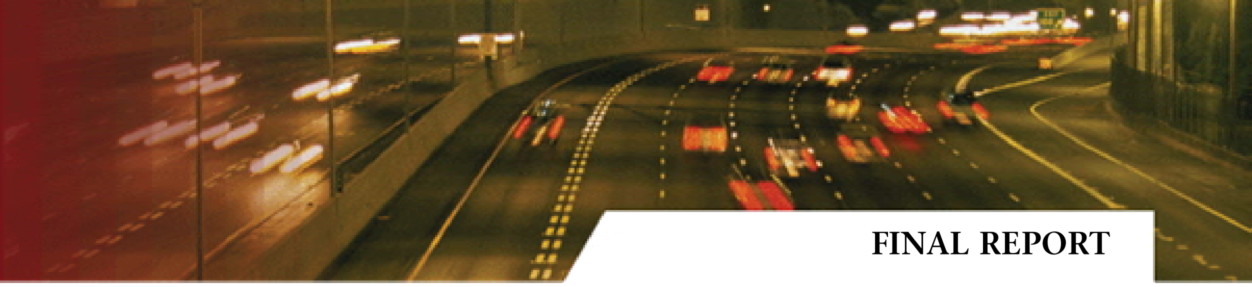
FINAL REPORT

CENTRALIZED STREET LIGHTING CONTROL AND MONITORING DEMONSTRATION PROJECT

PRINCE GEORGE, BRITISH COLUMBIA

PREPARED BY DMD AND ASSOCIATES LTD

MAY 23,2006



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Centralized Street Lighting Control and Monitoring Demonstration Project

Prince George, British Columbia

1. Introduction

The operation of street lighting consumes a significant amount of electricity, particularly when considered on a community, regional, Provincial, State or national basis. Reducing the amount of energy consumed by street lighting has the potential of providing significant savings to owners and reducing the burden on taxpayers and utility rate payers.

This paper describes a BC Hydro Power Smart demonstration project to reduce energy consumption through the remote dimming of street lights during late night hours using a new and innovative product, the Lumen IQ™.

The product supplier claims the Lumen IQ, when implemented as part of a Streetlight Intelligence Management System (SIMS), allows owners to vary the light output of individual street lights in a controlled manner and reduces energy consumption by matching actual lumen output to meet the lighting criteria for known variable conditions. The street lighting control is provided from a central location over the Internet. Signals are sent from the Internet through wireless links to each luminaire Additionally, the supplier claims the product allows owners to monitor performance of individual street lights, assess energy consumption and savings provided by dimming, perform data collection and provide improved maintenance through the use of their software that provides data analysis and information integration.

Street lighting levels are established through engineering design by applying minimum criteria based on the characteristics of the roadway and pedestrian conflict/activity levels. In North America, the Illuminating Engineering Society of North America uses the term "pedestrian conflict" in RP-8 *Recommended Practice for Roadway Lighting* (RP-8), while Canada's soon to be released *Guide for the Design of Roadway Lighting* uses the term "pedestrian activity," for roadways with sidewalks, although the application is identical to the IESNA. The higher the level of pedestrian conflict/activity, the higher the level of lighting recommended. The highest pedestrian conflict/activity level for an area or segment of roadway is used to establish the minimum lighting levels for the portion of roadway under consideration. Once the minimum level is established, street lights have traditionally provided that level of lighting throughout the hours of darkness as dimming technologies have been unavailable.

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Pedestrian conflict/activity levels do not necessarily remain constant throughout the hours of darkness, and in most instances the numbers of pedestrians present in a given area will be dramatically reduced in the late night and early morning hours when businesses are closed. Numbers of nighttime pedestrians may also be reduced based on the days of the week (weekday vs. weekend), seasonal factors, and other predictable dynamics. During hours of reduced pedestrian conflict/activity, the level of lighting provided could be reduced and while meeting recommended criteria for the actual level of pedestrians present. The Lumen IQ product claims to allow this reduction of lighting through controlled dimming of individual luminaires.

In this paper the demonstration project is described, the basis for, and advantages of managing individual street lights is discussed. Equipment requirements and claims for stated for the Lumen IQ product are examined compared to the results of independent laboratory testing. A discussion of the application of the technology to street lighting is also provided, along with cost saving estimates and performance measures being applied in this project.

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2. Demonstration Project Background

2.1 The BC Hydro Power Smart Program

BC Hydro is one of the largest electric utilities in Canada, serving more than 1.6 million customers in an area containing over 94 per cent of British Columbia's population. As an electric utility, the organization's purpose is "to provide reliable power, at low cost, for generations." Much of BC Hydro's power is generated from hydroelectric projects. Due to permitting issues and escalating construction costs, the probability of adding significantly to the organization's hydroelectric generation capacity is low with respect to anticipated future demand for power. Additional sources of electrical generation are also expensive and difficult to permit and build. Because the supply of electricity is limited, the organization is strongly committed to energy conservation as a means to assist in fulfilling its purpose.

To encourage energy conservation, BC Hydro has created and manages a "Power Smart" program. The program focuses on energy conservation, offering financial incentives for businesses and individuals to install proven technology that reduces energy consumption. To ensure that new energy saving technology is made available, the program also allows new and innovative products that promise energy conservation to be placed into service by a BC Hydro customer to verify claims and measure results. BC Hydro provides financial assistance with demonstration projects as well as a structured program to verify claims and actual energy savings.

2.2 Project Description and Location

In 2004, the City of Prince George, a BC Hydro customer, applied to BC Hydro and received Power Smart funding to apply the Lumen IQ variable dimming technology to a selected area of its street lighting network to test the various aspects of the technology, including energy conservation.

The project includes installing the Lumen IQ product as a retrofit to 170 existing street lights along 15th Street, a main arterial. The roadway meets the IESNA "Major" roadway classification as defined in RP-8. The decision to use 15th Street was based on known variable pedestrian volumes. Local transit buses are scheduled along the length of 15th Street until 8 p.m.

The limits of the project are shown in Figure 1 – Map of Project Limits.

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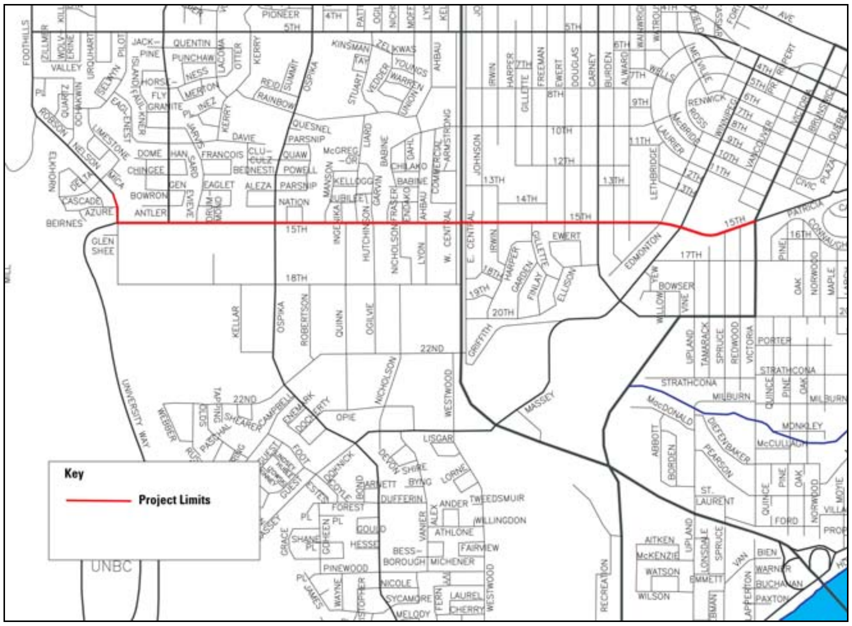

Figure 1 – Map of Project Limits

2.3 Project Participants

The demonstration project involves a number of organizations as described below.

2.3.1 BC Hydro

BC Hydro is the local electrical utility, and is providing funding for the demonstration project as part of its Power Smart program. If the application of the technology from this demonstration project is proven to be viable, BC Hydro will pursue installation of the technology on a wide spread basis to assist in meeting its energy conservation goals.

2.3.2 City of Prince George

The City of Prince George is the project proponent. As a municipality, the City provides a wide variety of services, including street lighting. The City has a keen interest in streamlining operations and reducing the cost of providing services to its citizens. In this regard, the City often pursues innovations that lead to cost reductions without sacrificing service. If this project is successful, the City may apply it to other locations, resulting in reduced energy and maintenance costs.

2.3.3 Streetlight Intelligence Inc. (STI)

Streetlight Intelligence is a publicly held company on the TSX Venture Exchange trading under the symbol "SLQ". STI designs, tests, manufactures and markets products for the high pressure sodium (HPS) street light industry. STI owns global rights to a patented "anti-cycling" technology that reduces the

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maintenance costs of streetlights. This anti-cycling technology is incorporated in the Company's Lumen IQ series of products that also provides owners with the ability to remotely dim or turn off streetlights according to user defined schedules. All of this is accomplished over the internet with STI's proprietary hardware and software. This combination of STI's proprietary hardware and software which creates these maintenance and energy savings is referred to as the STI "Streetlight Intelligence Management System" (SIMS).

2.3.4 DMD & Associates Ltd.

DMD & Associates is a privately held, Surrey, BC based consulting and electrical engineering firm with significant experience and expertise in the design of transportation-related electrical systems, including street lighting. DMD is currently producing a new *Guide for the Design of Roadway Lighting* for Canada, is very active in the Illuminating Society of North America (IESNA) Roadway Lighting Committee (RLC), and fully understands the theoretical and practical basis for street lighting. DMD's role in this project is to provide project coordination, coordinate testing, provide engineering analysis and provide verification of the claims of STI and the demonstration project in general.

2.3.5 British Columbia Ministry of Transportation (MOT)

The MOT is the owner and manager of Provincial roadways and related infrastructure throughout British Columbia. As the largest owner of street lighting infrastructure in British Columbia, the MOT has a keen interest in reducing energy costs and streamlining maintenance for its current and future street lighting infrastructure. The MOT is monitoring the progress and results of the demonstration project in order to assess it applicability to its street lighting network.

2.3.6 Insurance Corporation of British Columbia (ICBC)

ICBC is a provincial Crown corporation established in 1973 to provide universal auto insurance to BC motorists. In addition, the Corporation is responsible for driver licensing, vehicle registration and licensing. In addition to providing this basic insurance, the Corporation competes with other automobile insurance companies by offering extended third-party legal liability and other optional insurance coverage such as collision and comprehensive coverage. ICBC works with communities and stakeholder groups to help them take responsibility for their road safety challenges. Programs include a number of loss-prevention initiatives in pursuit of the financial benefits from reduced crashes, injuries and deaths. ICBC's interest in this project is to ensure that road safety provided by street lighting is not compromised. ICBC, in conjunction with the RCMP will provide applicable collision data for the project.

2.3.7 Royal Canadian Mounted Police (RCMP)

The Royal Canadian Mounted Police is the Canadian national police service and an agency of the Ministry of Public Safety and Emergency Preparedness Canada. The RCMP is unique in the world since it is a national, federal, provincial and municipal policing body. The RCMP provides total federal policing service to all

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Canadians and policing services under contract to the three territories, eight provinces (except Ontario and Quebec), approximately 198 municipalities and, under 172 individual agreements, to 192 First Nations communities. The RCMP will provide collision data for the project as well as provide comments on the applicability of street light dimming and control on policing activities.

2.3.8 Lighting Sciences Incorporated (LSI)

LSI is an independent product testing laboratory with a long track record related to testing street lighting and automotive lighting products. Their role in this project is to provide independent testing and verification of the operational claims of STI and the Lumen IQ product. Located in Scottsdale Arizona, the firm provides testing of luminaires in accordance with published IESNA test procedures. LSI is active with the IESNA Testing Procedures Committee and has participated in round robin testing with other laboratories. LSI is an approved test lab for the United States Department of Transportation (US DOT) for the testing of automotive lighting products. LSI has an ongoing testing project with the Texas Department of Transportation including electrical and photometric testing of outdoor lighting fixtures. LSI has have performed numerous independent tests for street lighting products for many government and commercial companies.

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3. Description of the Lumen IQ Technology

3.1 Overview

The Lumen IQ technology used in this project is best described in terms of its hardware components, communications systems, and software. Figure 2 – The Lumen IQ System Overview shows the general arrangement of the hardware (and software) and communications components.

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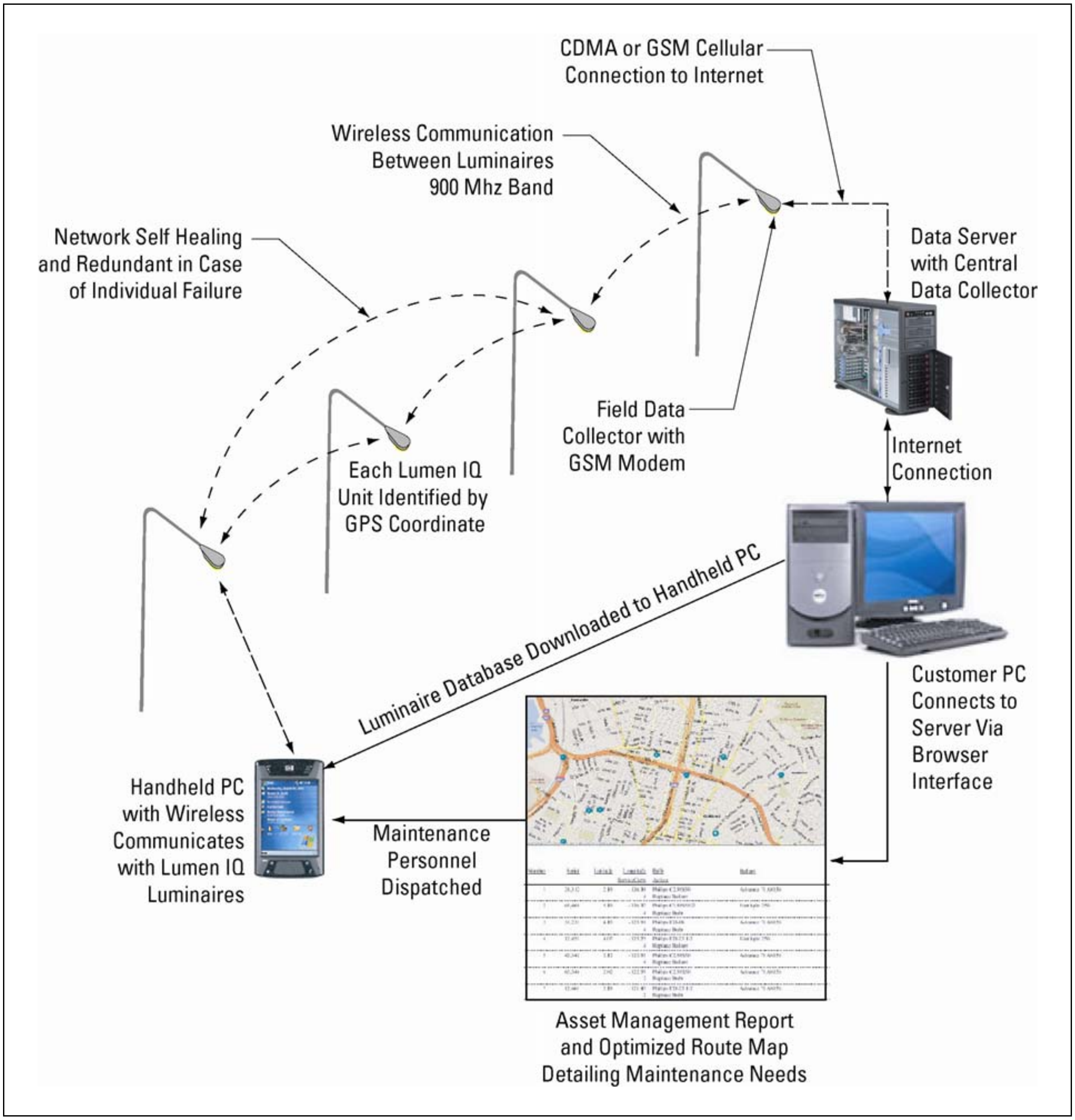

Figure 2 – The Lumen IQ System Overview

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3.2 Hardware Components

3.2.1 Lumen IQ Units

The Lumen IQ units are installed in the street light housings. The footprint of the Lumen IQ hardware is small and able to fit into typical cobra head luminaires. Each Lumen IQ unit controls the single street light in which it is installed. Functions controlled by the unit include on/off/dimming. Traditional night/day on and off functions are provided based on ambient light levels, while dimming is provided based on programming and feedback provided by a sensor unit.

The Lumen IQ dimming technology allows for 60 steps of dimming at approximately 1 percent increments. This allows the unit to dim the street light from 100 percent of output (no dimming) to 31 percent of full output.

The Lumen IQ unit also monitors the luminaire for cycling, and turns the street light off if cycling occurs to preserve other components (ballast, ignitor, etc.). If the luminaire has been turned off due to cycling, a trouble code is provided and sent to the central database. A flashing LED indicator which can be seen from the street is then activated, indicating to maintenance personnel that the luminaire requires maintenance.

Energy consumption is also monitored by the Lumen IQ unit. This allows owners to monitor the amount of energy used by the individual street light.

Figure 3 – Lumen IQ Elements shows the arrangement of the elements in the street light housing, including the following elements; Microprocessor unit with internal clock (A);Wireless 900 MHz radio frequency (RF) send/receive communications module with visible LED trouble indicator (B); Lamp lumen output sensor (C); Day/night sensor which functions in a manner similar to a photocell (D)

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Figure 3 – Lumen IQ Elements

The accuracy of the lamp lumen output sensor is critical to the dimming process and will be discussed in greater detail in the section detailing the results of testing. If the sensor is able to accurately measure the lumen output of the lamp and correctly correlate the output to the degree of dimming programmed, the desired lighting levels can be delivered.

If communication between the Lumen IQ unit and the central database fails (due to a knockdown, for instance), the dimming instructions which are stored in the microprocessor will be used to control the light until communications with the server is reestablished.

For identification, each Lumen IQ is given a unique identifying serial number. At the server level this number is associated with Global Positioning System coordinates for easy location using sophisticated mapping software.

3.2.2 Field Data Collectors (FDC)

FDCs consolidate and manage information from a group of Lumen IQ units via wireless communications. The FDC also communicates with the central computer (data server) that houses the software for managing and monitoring through wireless cellular telephone communications. The FDC is mounted in a separate external enclosure .

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3.2.3 Central Data Collector (CDC)

The Lumen IQ units are managed by a server containing central data collector (CDC) software. The CDC serves as a mid-tier application and manages the data from each Lumen IQ unit forwarded to the data server.

3.2.4 Data Server

The data server stores all of the data from each Lumen IQ unit in a series of linked databases, and provides information to and from the street lights and the customer's computer through a web interface. The server is located in a secure data facility, and can be accessed by customers and STI through a browser-based user interface. All data transfers are encrypted at the server to provide security. The server includes specialized software, including Microsoft MapPoint Server for coordinating location information.

3.2.5 Customer Personal Computer (PC)

The operation and monitoring of the individual Lumen IQ units is provided through standard browser software located on a standard personal computer (PC) running Microsoft Windows connected to the Internet. Typically this computer is located in the street lighting manager's office, although in practical terms any browser-equipped computer can be used as no special software is needed (communications with the server is accomplished through secured login authentication). Access to the data is provided through server-based middleware allowing control of the customer's Lumen IQ units. Via the browser interface, the PC sends and receives data to and from the CDC, which in turn communicates with the appropriate FDC and each Lumen IQ unit.

3.2.6 Handheld Data Collectors (HDCs)

Pocket PCs with wireless capabilities are used in the field to communicate with individual Lumen IQ units using specialized software through the 900 MHz band described below. This allows field personnel to communicate with the Lumen IQ units to perform maintenance operations such downloading trouble codes, setting up new units in the field or updating records with respect to lamp changes, etc. Because the serial number data provided to the software on the handheld is owner-specific, use of the handheld will be restricted to accessing the individual owner's street lights. The typical user of the HDC will be maintenance personnel, although STI also envisions potential future use by police and other agencies to turn lights on and off in emergencies.

3.3 Communications

3.3.1 Wireless Radio Frequency (RF) Network

Each Lumen IQ unit includes a custom 900 MHz wireless RF communications module. The 900 MHz band is unlicensed and requires no special permits. Multiple Lumen IQ units form a wireless network providing access to individual Lumen IQ units for monitoring and control from the FDC without the need for hardwired connections. The data stream is fully encrypted for protection. Redundancy is provided within the network because each communications module can communicate with its adjacent neighboring lamp providing a self-

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healing data path if one or more communications modules within the network should fail. Up to 500 Lumen IQ modules can be managed from a single FDC.

The wireless network is also utilized by HDCs to communicate with the individual Lumen IQ units by field personnel performing installation or maintenance activities.

3.3.2 Cellular Telephone Network

Each FDC is connected to the server containing the CDC and the Internet by Global System for Mobile Communications (GSM) or Code Division Multiple Access (CDMA) cellular telephone connections. GSM and CDMA are the typical mobile phone technologies used throughout the world. The data stream on the cellular telephone network is encrypted to provide security.

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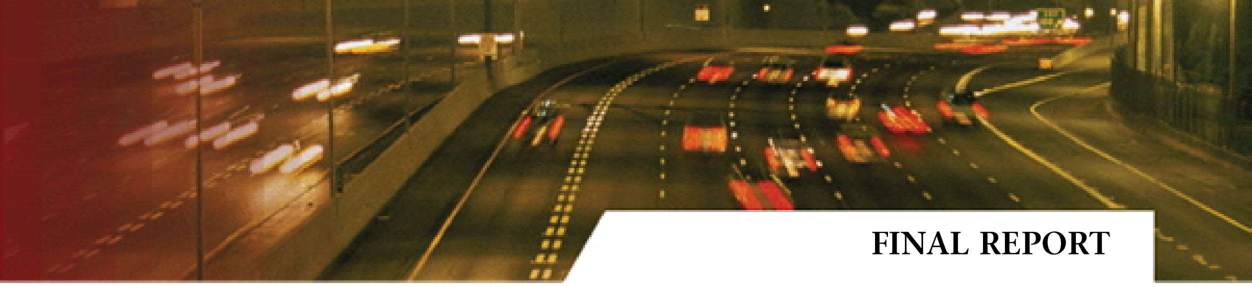

4. Benefits of Managed Street Lighting

The application of the STI Lumen IQ technology and SIMS system will provide a number of benefits to owners and the public. These benefits include significant energy conservation, reduction in obtrusive light during periods when the luminaires are dimmed, improved maintenance efficiency, electrical component protection for cycling luminaires, accurate measurement of power usage, and equipment performance data.

4.1 Energy Conservation

STI Lumen IQ technology and SIMS system is estimated to provide up to a 40 percent reduction in energy consumption based on dimming. Dimming, which reduces power consumption, allows for street lights to be operated at reduced output levels and still meet recommend criteria based on actual pedestrian levels. Dimming will also allow street lights to provide the minimum maintained level throughout the life of the lamp, rather than providing a higher initial level as is necessary with typical street lights. Dimming can also be applied to provide the proper light levels for areas where over lighting with traditional street lights is present due to uniformity criteria. The different scenarios are dealt with in detail in a later section of this report.

The Lumen IQ technology does not provide a 1:1 reduction in power consumption for a corresponding reduction in lumen output due to electrical losses of magnetic ballasts. Laboratory testing has shown that at a 50 percent level of lumen output, power input is reduced by approximately 40 percent. Electronic ballasts which will be incorporated into the SIMS system are being developed by at least two manufacturers. Electronic ballasts are more efficient than magnetic ballasts in converting input power to the proper lamp power, resulting in an overall lamp-ballast system efficacy increase. Testing is currently being undertaken by LSI to identify the efficiency of the Lumen IQ technology using electronic ballasts.

Although street lighting is widespread there is a surprising lack of information with respect to the actual percentage of total electrical load that can be attributed to its use. In Calgary, Alberta, the local utility Enmax estimated that commercial use consumes about 50 percent of electrical energy generated, while residential uses consume about one-third. The remainder is consumed by street lights and transportation. Conversations with various municipalities indicate that street lighting accounts for between 18 percent and 30 percent of municipal electrical load.

Owners will likely be most interested in dimming with respect to the cost of power and resultant budget impacts from street lighting. The major issue will be reducing the total cost of operations. For utilities and governments, the main issue with respect to dimming may be reducing peak load to delay or

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preclude the need to build energy infrastructure, including generation facilities which are increasingly difficult to permit and fund.

4.1.1 Reduction in Obtrusive Light

Any reduction in light output from a street light will result in corresponding reductions in obtrusive light, including spill light, sky glow and glare. The reduction in sky glow may be especially important to astronomers who may be able to schedule their observations during hours of increased dimming.

4.1.2 Improved Maintenance Efficiency

Monitoring of individual street lights from a desktop computer for conditions requiring maintenance will allow owners to provide maintenance in a more efficient manner. Individual street lights that are inoperable for any reason (electrical supply problem, component failure, knockdown, etc.) are identifiable using the Lumen IQ technology and SIMS system. In addition, the integrated mapping software, using Microsoft MapPoint server, is able to quickly provide routing for maintenance activities. Figure 4 – Maintenance Routing Map shows an example map. The current mapping process, typically driven by logging trouble complaints from the public, may take several man hours per day in a large city. The database software not only marks the location of the luminaire, it provides information regarding the fault and optimizes the best route for repairs. When maintenance personnel arrive at the trouble call site, the flashing LED on the bottom of the luminaire allows for easy identification in daylight, and through use of a handheld device the that contains maintenance and asset information, the maintenance personnel can switch the light on to observe its operation.

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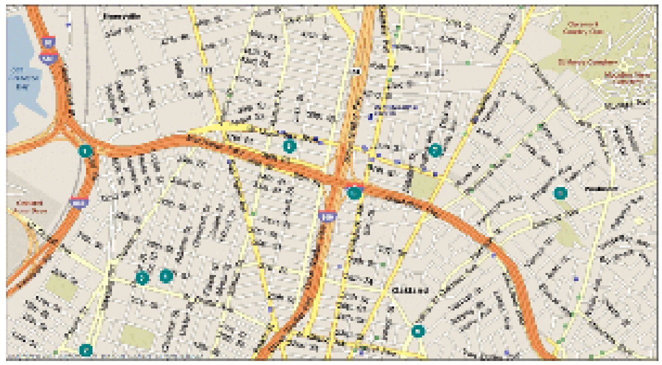

Number	Serial	Latitude	Longitude / ServiceCrew	Bulb / Action	Ballast
1	24,312	2.19	-126.38 4	Philips C250S50 Replace Ballast	Advance 71A8156
2	68,468	5.19	-126.37 4	Philips CL50S55/2 Replace Bulb	Firstlight 250
3	31,231	4.10	-125.58 4	Philips ED-18 Replace Bulb	Advance 71A8156
4	12,451	4.07	-125.25 4	Philips ED-23 1/2 Replace Ballast	Firstlight 250
5	42,342	2.12	-123.51 4	Philips C250S50 Replace Ballast	Advance 71A8156
6	65,546	2.82	-122.99 2	Philips C250S50 Replace Bulb	Advance 71A8156
7	12,461	2.18	-121.45 2	Philips ED-23 1/2 Replace Bulb	Advance 71A8156

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Figure 4 – Maintenance Routing Map

4.1.3 Electrical Component Protection for Cycling Luminaires

A key feature of the STI Lumen IQ product is the ability for the individual unit to turn off a lamp that is experiencing cycling, reducing negative impacts on other components of the street light (ballast, capacitor, igniter, etc.). This feature is provided by internal algorithms built into the Lumen IQ microprocessor unit that sense the characteristic electrical feedback associated with cycling. If cycling is detected, the Lumen IQ unit turns off the street light, energizes a flashing LED indicator visible from the street, and transmits a flag to the server noting the state of the luminaire and that it has been shut off due to cycling.

4.1.4 Accurate Measurement of Power Usage

Most street lights in North America are provided power on an unmetered (flat rate) basis, with power charges based on the hourly energy consumption of the devices for approximately 4100 hours of use per year. For unmetered street lights, the STI Lumen IQ technology and SIMS system will allow accurate measurement of power consumption regardless of the state of the street light (dimmed or undimmed). Once accepted by utilities as an accurate means to

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measure power consumption, owners will be billed for power actually used, taking full advantage of the energy saved. Use of this technology will end the shortcomings and abuses of the flat rate system, and make the full financial benefit of dimming available to owners. Power consumption data gathered by the Lumen IQ units and concentrated into the database will be available to the power company by online access through a web browser interface for billing purposes.

4.1.5 Equipment Performance Data

Because detailed records are kept with respect to individual street lights as measured by an accurate photoreceptor unit, and date-logged activities, the database of power use, lumen maintenance and other factors will serve as an accurate picture of the performance of luminaires, lamps and other components in the field. This information has not previously been available and will allow an owner to objectively compare the performance of products, track knockdowns and other maintenance problems, and provide for other analysis that may be specifically relevant to design, operations, and maintenance.

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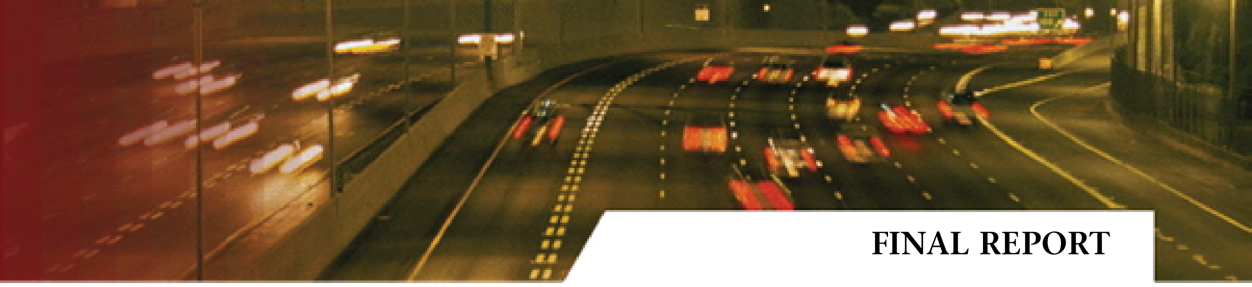

5. Results of Lumen IQ Laboratory Testing

Dimming street lighting to provide lower levels during known periods of lower pedestrian conflict is a relatively simple concept, but requires a predictable level of accuracy and response from the street lighting equipment, as well as a relatively fine degree of adjustment to achieve maximum energy efficiency.

Lighting Sciences Incorporated (LSI) of Scottsdale, AZ, provided independent laboratory testing to verify the performance of the STI Lumen IQ system. Tests were performed, as required, in LSI's laboratory using a moving mirror goniophotometer or computerized integrating sphere.

The analyzed results of the testing program showed the following results.

- The spectral response of the Lumen IQ day/night sensor matches the eye more closely than a typical silicon detector. The day/night sensor works in a fashion similar to a typical street light photocontrol, turning the fixture on at dark, and off in the daytime. The results of this test verify the Lumen IQ's day/night sensor is able to sense/day night transitions more accurately than an uncorrected silicon detector, and will turn the street light on and off as required in a typical street light.

- The Lumen IQ lamp sensor accurately measures lumen output at every level of dimming (linear correlation). When the Lumen IQ microprocessor instructed the lamp to achieve a predetermined level of output (say 80 percent), the lamp sensor was very reliable in measuring the actual output of the lamp. Tests performed showed a linear correlation between the computerized integrating sphere and the Lumen IQ lamp sensor with an R^2 value of 0.99 for tests at all dimming levels.

- The Lumen IQ is able to dim the lamp in very fine increments so that lighting output levels will meet the recommended criteria for street lighting given the type of road and pedestrian conflict level. The results of testing showed that the Lumen IQ is able to provide dimming in 1.1 percent increments, producing a level control that will allow the actual lighting level to meet the recommended level in IESNA RP-8 when the lamp is dimmed. This level of "granularity" in control of the lumen output level ensures that the product is able to dim the light to the proper level for a lower pedestrian conflict level.

- The Lumen IQ dimming operations did not affect lumen distribution from the luminaire. In other words, as the luminaire was dimmed, the pattern of the luminous flux was constant. These results implied no change to the manufacturer's specification datasheet representing lumen distribution on the ground when the Lumen IQ unit is used. A street light under control of Lumen IQ will deliver the same pattern of luminous flux

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to the surface being lighted at every level of dimming, thus maintaining the same uniformity in either dimmed or undimmed states. This is important as uniformity is a key criterion in street lighting design. A moving mirror goniophotometer was used to test a fixture under control of the Lumen IQ system at full power and at maximum dimming. The tests showed the relative intensity distributions were identical to within the accuracy of the test.

- A linear correlation was shown to exist between lumen output and power input throughout the dimmed levels. The linear correlation expresses the benefit of dimming to the owner, which is reduced power consumption in the dimmed mode. This test was performed on six different lamp and ballast combinations in a computerized integrating sphere over the entire dimming range. Lumen output to power input plots confirmed a linear relationship in each instance.

- No negative effects due to power factor were shown in dimming operations, verifying that conductor size changes are unnecessary for installation of the Lumen IQ technology. Six lamp and ballast combinations were tested by LSI. Maximum power draw occurred at the zero dimming level (100 percent output) in all instances. Owners installing the Lumen IQ do not have to perform electrical calculations for added load when installing the technology.

- Dimming operations are performed equally well with single or dual arc tube lamps. LSI concluded that, "Lamp lumen output and lamp power output under Lumen IQ control is quite similar with either single arc tube or dual arc tube lamp designs." Single arc tube lamps were noted to have a slightly higher lumen output compared to dual arc tube lamps due to light absorption by the standby light tube. The design issues and advantages/disadvantages related to dual arc tube lamps are not explored in this paper, but the testing confirms that if a project is properly designed for dual arc tube lamps the owner can expect to receive the same benefits from dimming using the Lumen IQ technology.

- Lighting Sciences confirmed that dimming to 50 percent of lumen output over a period of five minutes is sufficient for eye adaptation and would be difficult to perceive. This opinion was not related to testing, and was based on LSI personnel's expertise in lighting sciences. STI asked for an opinion on this issue to assist in developing a reasonable strategy for the initiation of dimming operations with minimal impact on public response.

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6. Potential Scenarios for the Application of Street Lighting Dimming

6.1 Overview

The installation of street lighting is an engineering decision whose goal is to "provide quick, accurate and comfortable visibility at night" (RP-8 page 1). Research has shown that the installation of lighting on roadways with significant volumes of vehicular and pedestrian traffic will reduce collisions, providing increased safety for roadway users. This section describes the scenarios where the technology is being applied to the roadway lighting for this project, resulting in energy savings for the owner. These scenarios include the following.

- **Roadways with Varying Pedestrian Conflict Levels**. A portion of the roadway included in the study is examined with respect to the opportunities for dimming. A typical arterial section is also presented.
- **Dimming Street Lights to the Maintained Level.** This discussion focuses on the energy savings available if the luminaire is dimmed only to the minimum maintained level for its useful life.
- **Areas Over Lighted to Meet Uniformity Requirements**. Areas are often over lighted to meet uniformity requirements due to equipment limitations. A typical scenario is discussed.

6.2 Roadways with Varying Pedestrian Conflict Levels

The amount of light provided by a street lighting installation is typically based on two significant engineering criteria – the classification of the roadway itself and the level of pedestrian conflict (known as pedestrian activity in the soon to be released TAC Design Guide for Roadway Lighting, which uses similar criteria to the IESNA). In North America, the criteria and associated lighting levels are established by IESNA publication RP-8, and are shown in Figure 5 – IESNA Illuminance Criteria for Roadways. As noted in the figure, for a given roadway classification, higher illuminance levels are required for higher levels of pedestrian conflict.

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Road and Pedestrian Conflict Area		Pavement Classification (Minimum Manintained Average Values)			Uniformity Ratio	Veiling Luminance Ratio
Road	Pedestrian Conflict Area	R1 lux/fc	R2 & R3 lux/fc	R4 lux/fc	E_{avg}/E_{min}	L_{vmax}/L_{avg}
Freeway Class A		6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Freeway Class B		4.0/0.4	6.0/0.6	5.0/0.5	3.0	0.3
Expressway	High	10.0/1.0	14.0/1.4	13.0/1.3	3.0	0.3
	Medium	8.0/0.8	12.0/1.2	10.0/1.0	3.0	0.3
	Low	6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Major	High	12.0/1.2	17.0/1.7	15.0/1.5	3.0	0.3
	Medium	9.0/0.9	13.0/1.3	11.0/1.1	3.0	0.3
	Low	6.0/0.6	9.0/0.9	8.0/0.8	3.0	0.3
Collector	High	8.0/0.8	12.0/1.2	10.0/1.0	4.0	0.4
	Medium	6.0/0.6	9.0/0.9	8.0/0.8	4.0	0.4
	Low	4.0/0.4	6.0/0.6	5.0/0.5	4.0	0.4
Local	High	6.0/0.6	9.0/0.9	8.0/0.8	6.0	0.4
	Medium	5.0/0.5	7.0/0.7	6.0/0.6	6.0	0.4
	Low	3.0/0.3	4.0/0.4	4.0/0.4	6.0	0.4

Figure 5 – IESNA Illuminance Criteria for Roadways

Current and past practice has been to establish pedestrian conflict levels by counting the number of pedestrians on the sidewalk in a single block (or 200 m segment) for a given one-hour nighttime sample period (typically between 18:00 and 19:00 hours). The sample period is typically the hour of highest nighttime pedestrian conflict. If 100 or more pedestrians are counted, the pedestrian activity conflict is high; if 11 to 99 pedestrians are counted, the pedestrian activity level is medium conflict; if 10 or fewer pedestrians are counted, the pedestrian conflict level is low.

Once the pedestrian conflict level has been established, the minimum level of lighting is determined from the table in Figure 5 – IESNA Illuminance Criteria for Roadways. This level of lighting is then provided throughout the hours of darkness.

It is well-known that pedestrian conflict levels do not remain constant throughout the hours of darkness for a given portion of roadway, and in most instances the numbers of pedestrians present in a given area will be dramatically reduced in the late night and early morning hours when businesses are closed. Numbers of nighttime pedestrians may also vary throughout the night due a wide variety of additional circumstances including the following.

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- Weekdays vs. weekends
- Seasonal factors
- Local events such as festivals, celebrations, or sporting events in a stadium district

The application of the Lumen IQ product for significant energy savings depends on the knowing variance of pedestrian activity/conflict levels throughout the hours of darkness. During hours of reduced pedestrian conflict, the level of lighting provided could be reduced (with reduced energy consumption) to the recommended criteria for the actual level of pedestrians present. The Lumen IQ product claims to allow this reduction of lighting through controlled dimming of individual luminaires. Because dimming does not affect the distribution pattern of the luminaire, uniformity ratios are preserved, even with reductions in luminaire output.

This scenario is the main focus of the BC Hydro Power Smart study, since the opportunity for energy savings is obvious and substantial. A section of roadway is being analyzed for the study and is described in later in the paper.

Owners typically have little data with respect to pedestrian conflict levels for lighted roadways. Actual energy savings potential may increase under this scenario as pedestrian patterns are better analyzed and understood by owners. In downtown core areas or stadium districts with complex patterns of pedestrian activity tied to holiday and event schedules, the opportunities for dimming may be more or less significant than in areas with predictable volumes of pedestrians at regular hours once pedestrian behavior is better understood.

A calculation for a typical arterial roadway lighted to a level for high pedestrian conflict in the study area is shown below in Figure 6 – Typical Roadway with High Pedestrian Conflict.

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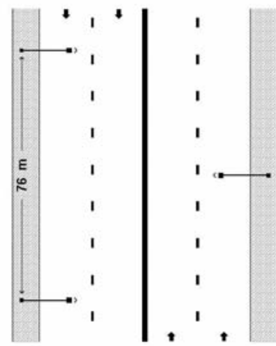
Design Information

Project	STI
Number	967
Name	MK
Company	DMD



Roadway Information

Number Left Lanes	2
Left Lane Width	3.5 m
Median Width	0 m
Number Right Lanes	2
Right Lane Width	3.5 m
Calculation Method	IES RP8-2000
Pavement Reflectance	Asphalt - R3
Roadway Classification	Major
Pedestrian Conflict	High

Luminaire Information

	Left Side	Right Side
Label	A	A
Catalog Number	Not specific to a single Catalog Number.	Not specific to a single Catalog Number.
Photometric File	GE1006.IES	GE1006.IES
Lamp Lumens	27000	27000
Light Loss Factor	0.72	0.72
Input Power	250 W	250 W
Tilt	0°	0°
Arm Length	3 m	3 m
Mounting Height	9 m	9 m
Setback	1.2 m	1.2 m
Quantity	14	13

Calculation Results - Left Side

Luminance			Illuminance					
Average	1.1	cd/m²	Average	17.0	lux	Lv Ratio	0.2	
Max	2.0	cd/m²	Max	36.7	lux	STV	3.0	
Min	0.4	cd/m²	Min	8.0	lux	Spacing	76	m
Max/Min	5.0		Max/Min	4.6		Length	1000	m
Avg/Min	2.8		Avg/Min	2.1		Quantity	27	

Figure 6 – Typical Roadway with High Pedestrian Conflict

The opportunity for reducing energy on this type of roadway dimming using existing IESNA recommended criteria is to reduce lumen output to a medium or low pedestrian conflict level. This will result in a corresponding reduction in lumen output of 30 percent and 50 percent respectively, and an energy savings of approximately 40 percent at the 50 percent dimming level as verified by laboratory testing.

When dimming is energized, the Lumen IQ product will reduce the lumen output of the lamp over a five minute period in approximately 1 percent increments. Consultation with Dr. Ian Lewin of Lighting Sciences Incorporated confirm that changes in lumen output in 1 percent increments are virtually imperceptible, and that dimming to a 50 percent level over five minutes is sufficient for normal eye adaptation.

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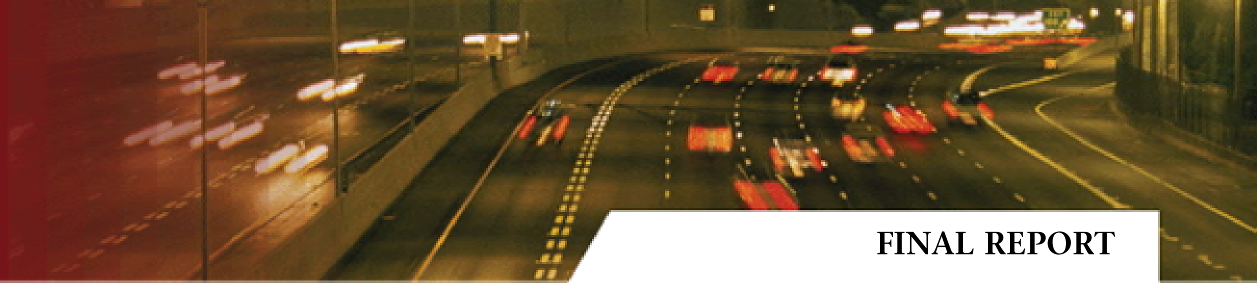

Energy savings opportunities from dimming under this scenario will obviously depend on a number of factors, including the following.

- Identifying candidate roadways for dimming. Owners may discover that roadways are under lighted for current conditions and dimming does not apply.
- The number of hours that the roadway can be dimmed. While it is assumed that most roadways experience substantial decreases in pedestrian activity in the late night and early morning hours, each situation will require analyses to determine actual pedestrian conflict levels at different hours.
- Showing that collision rates are not increased. Because lighting is a roadway safety measure, the police, attorneys and insurance companies will have an interest in the number of collisions under dimmed conditions. If the results are positive, dimming will be accepted.

6.3 Dimming Street Lights to the Maintained Level

Typical street lighting installations, which are nearly all based on high intensity discharge (HID) lamps, are designed to provide a minimum lighting level. Because HID lamps used in street lighting, such as high pressure sodium (HPS) and metal halide (MH), depreciate as they are operated over their useful life, designers must provide an initial level of lighting higher than the minimum maintained level. Throughout the maintenance cycle, the power consumption remains constant while the amount of light provided decreases as the lamp lumens depreciate.

Application of the Lumen IQ technology would allow the street light to operate at its maintained level for the entire maintenance cycle based on reduced power input, saving a energy. To accomplish this, the Lumen IQ unit would be programmed to dim the light output to the maintained level as the maximum.

An internal study by STI predicts payback of the Lumen IQ unit controlling a single-arc tube 250-watt lamp under this scenario with no additional dimming at between 7.5 to 14 years, depending on the lamp used (lamp lumen maintenance curves differ significantly from manufacturer to manufacturer). Typically, the payback period identified by this internal study is reduced as the wattage increases, with payback on a 400-watt lamp at between 4.7 and 8.7 years.

While the payback period under this scenario appear to be quite long for lower wattage lamps, the benefits of the energy savings on a macro scale may be significant enough to warrant widespread installation of dimming technology if this strategy would delay or preclude the construction of costly generating

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facilities. This is due to the widespread use of street lighting, which places considerable demand on available grid power during peak use hours.

6.4 Dimming in Areas Over Lighted to Meet Proper Uniformity

Because HID lamp wattages are fixed, some areas served by street lighting are over lighted to meet uniformity criteria, which is the driving factor in the luminaire spacing. This may be the result of the lack of a lamp in the appropriate wattage (the design requires a 160-watt lamp, which is not available, so a 200-watt lamp is used), or because an owner has standardized on a particular pole/luminaire combination for maintenance purposes.

For instance, it is common in the lower mainland of British Columbia for municipalities to have standardized on 7.5 m poles combined with a 100-watt, full-cutoff luminaire for street lighting in suburban neighborhoods. A design calculation is shown in Figure 8 – Typical Suburban Neighborhood Calculation Example.

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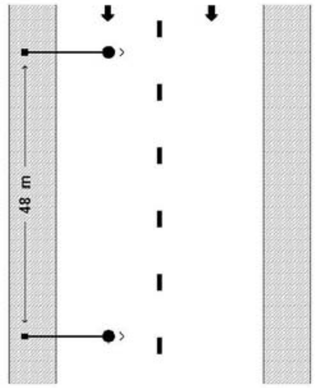
Design Information

Project	STI
Number	967
Name	MK
Company	DMD

Roadway Information

Number Left Lanes	2
Left Lane Width	4 m
Median Width	0 m
Number Right Lanes	0
Right Lane Width	0 m
Calculation Method	IES RP8-2000
Pavement Reflectance	Asphalt - R3
Roadway Classification	Local
Pedestrian Conflict	Low



Luminaire Information

Left Side

Label	A
Catalog Number	(not specific to a single catalog number)
Photometric File	GE7286.IES
Lamp Lumens	9500
Light Loss Factor	0.80
Input Power	100 W
Tilt	0°
Arm Length	3 m
Mounting Height	7.5 m
Setback	1.2 m
Quantity	21

Calculation Results - Left Side

Luminance			Illuminance					
Average	0.5	cd/m²	Average	7.4	lux	Lv Ratio	0.3	
Max	1.1	cd/m²	Max	28.9	lux	STV	4.4	
Min	0.1	cd/m²	Min	1.3	lux	Spacing	48	m
Max/Min	8.8		Max/Min	22.0		Length	1000	m
Avg/Min	4.0		Avg/Min	5.7		Quantity	21	

Figure 8 – Typical Suburban Neighborhood Calculation Example

IESNA criteria recommend 4.0 lux at 6.0:1 average-to-minimum uniformity in this situation (local roadway with low pedestrian conflict). To meet the uniformity criteria, the roadway must be over lighted by 54 percent. Using the Lumen IQ technology, the lamp can be dimmed, resulting in a corresponding annual savings in power of over 40 percent. Additional savings would be realized from reducing the lamp output based on lumen maintenance.

While this scenario is not the focus of the Prince George Study, the savings potential may be significant for many communities. Payback periods for such scenarios would typically be approximately four years given the power rates in British Columbia (6.6 cents per kilowatt hour).

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7.0 The Prince George Study

Because the BC Power Smart study was in its infancy at the time papers for the conference were due, only a short portion of roadway was analyzed for this presentation. The results were then applied to the entire project area to show potential payback.

The study project is located on a four lane roadway that serves as one of Prince George's main arterials. The IESNA classification as determined from Figure 3 – IESNA Illuminance Criteria for Roadways is a major roadway. The roadway is served by municipal buses, adding to the number of pedestrians using the sidewalk and street. Bus service on the roadway terminates at 8 p.m. All luminaires that will have dimming applied are 250-watt HPS drop lens style fixtures and will be retrofit with the Lumen IQ technology.

7.1 15th Street at Spruce (Representative Area in the Study Project)

The owner has identified the area east of Spruce Street as a high pedestrian conflict area until 8 p.m. After 8 p.m. the pedestrian conflict level has been estimated by the owner to be low, due to the few businesses being open late and lack of bus service. The area west of Spruce was deemed to be a medium pedestrian conflict area until 8 p.m. After 8 p.m., the pedestrian conflict level was estimated to be low.

A third dimming scenario may be applicable to the project, which is dimming from a high pedestrian conflict level to a medium pedestrian conflict level. The percentage of dimming and energy savings for this scenario would be similar as dimming from a medium pedestrian conflict level to a low pedestrian conflict level.

The location is shown in Figure 9 – Aerial Photo of 15th Street at Spruce that shows the levels of pedestrian conflict identified by the owner.

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Figure 9 – Aerial Photo of 15th Street at Spruce

Figure 10 – 15th Street Approaching Spruce Eastbound shows the roadway from a passenger vehicle on 15th Street. The area is characterized by commercial businesses and nearby residential developments and schools.

Figure 10 – 15th Street Approaching Spruce Eastbound

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DMD acquired a drawing of the roadway along with mounting heights, arm length, luminaire types and wattages, and other items required to analyze the existing conditions regarding the lighting.

A number of observations were made with respect to the installation.

- Street lights along the length of 15th Street project are owned by a number of jurisdictions. Ownership included the City, lights leased from the local utility, and lighting owned by the British Columbia Ministry of Transportation (MoT), the equivalent of a State Department of Transportation. This fact may complicate the project as in-place agreements and labor contracts with the various entities will likely preclude the City from providing modification to those street lights. This situation will be carefully analyzed and dealt with in the application of the dimming.

- Spacing between poles is inconsistent. This is shown in Figure 11 – Pole Spacing at 15th and Spruce. This factor, while a concern with respect to the original design, may or may not be considered a limiting factor for the application of the dimming. In effect, if the original uniformity ratios did not meet the criteria for the roadway classification, the owner would not incur additional liability with the roadway under dimmed conditions as dimming will not alter uniformity. Due to unequal pole spacing, the calculation for this section of roadway required that the entire length of roadway under consideration be calculated, rather than using standard procedure of calculating for typical luminaire spacing. At the time this paper was written the issues related to uneven pole spacing were under further discussion.

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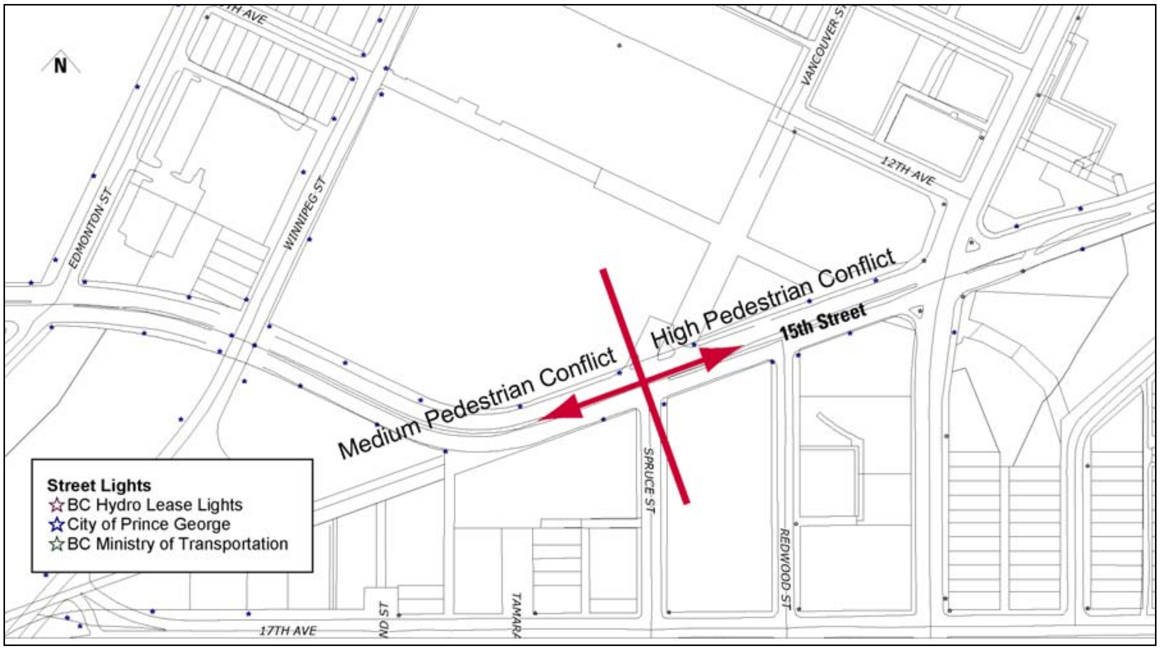

Figure 11 – Pole Spacing at 15th Street and Spruce

7.2 Situations Where Dimming is Not Applicable

A review of the rationale behind roadway lighting design criteria has led to the identification of the following areas where dimming is not applicable. The list is preliminary.

- Signalized Intersections. Signalized intersections typically include pedestrian crossings. It was decided not to dim signalized intersections as a safety measure as pedestrian conflicts with vehicles are very likely at signalized intersections even during low pedestrian conflict periods.

- Mid-Block Crosswalks. The decision not to dim mid-block crosswalks follows the same logic as stated for signalized intersections.

- Roundabouts. Due to the complex geometry in roundabouts and the ineffectiveness of fixed headlights within the tight roundabout circle, it was determined that dimming should not be applied to these facilities. Roundabouts are a replacement for signalized intersections, and may also contain pedestrian crossings.

- Rail Crossings. Rail crossing lighting is provided for detection of the trains and not related to pedestrian conflict levels, therefore dimming does not apply to these facilities.

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- Illuminated Signs. Illuminated signs are not part of the roadway surface and not related to pedestrian conflict levels, therefore dimming will not be applied to these facilities.

7.3 Dimming and Cost Savings

A calculation was made to verify the lighting levels were consistent with IESNA criteria for two blocks on either side of Spruce Street. Illumination levels were found to be consistent with a high pedestrian conflict level for a major roadway east of Spruce, and a medium pedestrian conflict level west of Spruce. Uniformity ratios, as suspected, did not meet IESNA criteria. The results of the calculation are shown below in Table 1 – Calculation Results at 15th and Spruce and IESNA Criteria.

Roadway Section Considered	Pedestrian Conflict Level	Calculated Illumination Level (lux)	IESNA Rec'd Illumination Level (lux)	Calculated Uniformity E_{avg}/E_{min}	IESNA Rec'd Uniformity E_{avg}/E_{min}
Two Blocks East of Spruce	High	17.6	17.0	12.6:1	3.0
Two Blocks West of Spruce	Medium	13.5	13.0	9.0:1	3.0

Table 1 – Calculation Results at 15th and Spruce and IESNA Criteria

Based on the owner's observations regarding the significant change in pedestrian conflict levels as bus service terminates, dimming could be applied after 8 p.m. For the area east of Spruce, the dimming level would be approximately 50 percent, dimming from a high pedestrian conflict level to a low pedestrian conflict level. For the roadway west of Spruce, the dimming would be 30 percent, dimming from a medium pedestrian conflict level to a low pedestrian conflict level.

For the purposes of this paper, it is assumed that dimming will take place during hours of darkness from 8 p.m. to 6 a.m.

Even with these simple parameters calculating the number of hours dimming will take place is not an easy task. To accurately determine the subject number of hours a table of sunset and sunrise times (modified for daylight savings time, if applicable) must be developed and the number of hours that meet the criteria for dimming must be applied – it must be dark, and it must be after 8 p.m. and prior to 6 a.m. Due to seasonal changes in sunrise and sunset times, the 10 hour period must be reduced. For the purposes of this paper we will assume dimming will be applied for an average of 8.0 hours per night, or 2920 hours per year. This means that of the 4100 hours commonly accepted as the number of hours a photocell-controlled street light operates, approximately 71 percent of those hours are available for dimming.

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For the Prince George project, the consultant assumes that 40 percent of the lighting along 15th Street can be dimmed from a high pedestrian conflict level to a low pedestrian conflict level after 8 p.m. (approximately 50 percent dimming). The remainder of the lighting is assumed to fall into the other category – that is the lighting is currently designed to a medium pedestrian conflict level and can be dimmed to a low pedestrian conflict level (30 percent dimming). This is shown in Table 2 – Number and Percentage of Luminaires to Be Dimmed in this Project.

Total Number of Luminaires for this Project	Number and Percentage of Luminaires to be Dimmed 50 Percent		Number and Percentage of Luminaires to be Dimmed 30 percent	
	Number	Percentage	Number	Percentage
170	68	40	102	60

Table 2 – Number and Percentage of Luminaires to Be Dimmed in this Project

Power consumption for a 250-watt luminaire is assumed to be 305-watts (input watts) given electrical losses. Table 3 –Savings per Luminaire at Anticipated Dimming Levels shows the savings anticipated for a single fixture assuming dimming to 50 percent of lumen output results in a 40 percent reduction in energy consumption and dimming to 30 percent of lumen output results in an approximate 25 percent reduction in energy consumption.

Fixture Input Watts	Dimming Level Applied	Consumption with Dimming	Fixture Watts (Dimmed)	Estimated Hours Dimmed per Year	Total Annual Consuption Under Dimming	Power Costs per kWh (C$)	Total Power Cost (C$)	Estimated Annual Savings from Dimming per Fixture (C$)	Number of Luminaires Dimmed (Study Project)	Total Annual Savings from Dimming for Pedestrian Conflict (C$)
305	0%	100%	305.00	2920	890.6	$0.066	$58.78	$0.00	0	$0.00
305	50%	60%	183.00	2920	534.36	$0.066	$35.27	$23.51	68	$1,598.81
305	30%	75%	228.75	2920	667.95	$0.066	$44.08	$14.69	102	$1,498.88
									Total	**$3,097.68**

Table 3 –Savings per Luminaire at Anticipated Dimming Levels

Total energy savings for all 170 luminaires is estimated to be 46,934 kWh. Total yearly dollar savings based only on dimming to lower pedestrian conflict levels will be $3097.68. Note the actual hours of dimming has been adjusted so payback has varied from what is listed.

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7.4 Additional Costs

Additional costs required for the installation and operation of the Lumen IQs includes computer equipment, handheld computers (HDCs) and system management. Wireless communications fees will also add a monthly fee of approximately C$.07 per pole per month. Mapping and routing features, which rely on queries to a Microsoft MapPoint server for each map generated (each screen redraw or each route generated) have a per transaction cost however these costs were waved for this project.

7.5 Payback

The cost of retrofitting a fixture with the Lumen IQ technology is approximately C$135, including parts and labor (installation costs to mount the fixture on the pole by maintenance personnel is not included). The total value for retrofitting the 170 luminaire in the Prince George Demonstration project is therefore estimated at $C22,950.

Yearly return on investment from energy savings for all 170 luminaires is $3097.68, not taking into account the savings from dimming for lumen maintenance. This means the Lumen IQ units will pay for themselves with energy savings from pedestrian conflict level dimming alone in 7.4 years. Including savings from lumen maintenance dimming will significantly reduce the payback period. Savings from maintenance efficiencies gained and expenses from additional costs are not included in this calculation. Note the payback varied as the hours of dimming were adjusted and re-adjusted from a 8PM dimming turn on to a 10PM dimming turn on. As pedestrian activity levels were defined by the City we were not directly involved in the duration of the dimming.

Additional advantages provided by the Lumen IQ are anticipated to reduce payback when considered in the overall picture. In discussing the system and its potentials with local municipal organizations, streamlining of maintenance is seen as a desirable factor. Many municipal organizations are interested in the Lumen IQ technology with maintenance management features as the primary focus. Other systems with similar maintenance management features are currently available (such as Telemics) , but those systems lack the dimming and system damage control capabilities of the Lumen IQ technology.

With regard to payback it is important to note that British Columbia power rates are among the lowest in North America. Rates in New York City and Oakland California are C$0.318 (US$0.240) per kWh and C$0.166 (US$0.125) per kWh respectively, while British Columbia power rates are C$0.066 per kWh. Payback periods for areas with higher rates will obviously be much shorter.

7.7 Field Testing

On March 3, 2006 field testing was undertaken on site. The purpose of the field testing was to measure the change in light levels as the lumen output of lamps

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is reduced from 100% lumen output at normal operation to 70% by STI's system and verify that the measurement methodology used provides consistent results. Testing was undertaken via a joint effort between STI and BC Hydro.

For the eight months proceeding March 3, approximately 76 streetlights have Lumen IQ controllers controlling the on/off time and the level of lighting. In March 2006 the updated versions of the Lumen IQ, with total communication capabilities were installed in these units. To meet the objectives it was determined that measurements would be done on 5 operating lamps on 15th Avenue which were on their own isolated contactor. These lamps were 250 watt HPS with a nominal operating voltage of 240 volts.

A standardized photometer VL-3704 from Gigahertz Optik Inc was used to measure light level changes.

Also involved was the STI's lamp sensor module which is positioned inside the lamp reflector for each of the five lamps. It is considered considerably accurate because it is not affected by any ambient light conditions. The units of measurement of the STI's lamp sensor module are analog to digital values (ADC counts).

The light measurement procedures are described as follows:

- The photometer was set up as per Figure 12 and five markers, measuring 5 inch x 5 inch were placed underneath the five poles on the ground. The markers were placed approximately 5 feet from the base of the pole at the roadside edge of the sidewalk. These markers were placed at the same distance from each of the lamps to establish uniformity for all the readings.
- The five lamps were ignited simultaneously and warmed up for a period of 15 minutes to stabilize the light output from the lamps. The stabilization of the light output was confirmed by STI's Lumen IQ lamp sensor values observed by Gerry Kurz (STI) remotely, from his office in Victoria, BC with the help of Lumen Station controlled via the internet.
- The value of the STI's Lumen IQ lamp sensor was recorded for each of the five lamps for 100% operation.
- Light measurements were taken for each of the five lamps at 100% operation. The Gigahertz Optik photometric field sensor was placed in the centre of the previously placed markers. The light output measured by the Gigahertz Optik photometric field sensor value was measured and recorded. The measurements were performed carefully so as to avoid any ambient light from the passing traffic on the road.
- The lumen output from the five lamps was simultaneously reduced by 30% by Gerry Kurz from the STI office in Victoria. The lamps were

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allowed to stabilize for 15 minutes to allow the measurements of the STI's Lumen IQ lamp sensor values, and the Gigahertz Optik photometric field sensor values.The new value of the STI's Lumen IQ lamp sensor was recorded for each of the five lamps at 70% of lumen output.

- Light measurements were taken for each of the five lamps at 70% lumen output. The Gigahertz Optik photometric field sensor was placed in the centre of the previously placed markers for the second time. The light output measured and recorded. The measurements were performed carefully so as to avoid any ambient light from the passing traffic on the road.

Luminaire Number	Light Meter Value (fc)	STI's Lumen IQ lamp sensor value (ADC counts)
1	2.624	103
2	1.5605	163
3	1.4125	89
4	2.061	64
5	1.9761	105

Table 4: Light output at 100% light level for the five luminaires

Luminaire Number	Light Meter Value (fc)	STI's Lumen IQ lamp sensor value (ADC counts)
1	1.99	73
2	1.18	114
3	1.06	63
4	1.63	45
5	1.5	75

Table 5: Light output at 70% light level for the five luminaires

Table 6 below represents the percentage difference of the values record between the Lighting Meter Value and The STI Lumen Sensor Value.

Luminaire Number	Light Meter Value (fc)	STI's Lumen IQ lamp sensor value (ADC counts)
1	24%	29%
2	24%	30%
3	25%	29%
4	21%	30%
5	24%	29%

Table 6: Percentage Difference of values in columns 2 & 3 from Tables 3 & 4

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The values recorded by the light meter on the surface of the road were greatly affected by the higher ambient light levels from the surrounding streetlights and automobiles in comparison to STI's Lumen IQ lamp sensor inside the reflector. Hence, it was expected that the percentage value measured by STI's Lumen IQ lamp sensor value (ADC counts) would be more accurate to a laboratory setting than the values recorded by the field sensor.

Also, it was observed that the Field sensor values among the lamps had a standard deviation of 0.47 fc according to Table 3 (column # 2) and 0.37 fc according to Table 5 (Column #2). This variation could be attributed to the varying ambient light conditions for each lamp and the variations in the fixture itself. In retrofitting the fixtures for this project it was observed that there were several different manufactured models of fixtures and that the fixture seemed to vary in age. The different models and age may have an effect on the photo metrics of the reflectors which may vary the lumen output observed.

On the basis of the measurements it was identified that the lamps had to be adapted to a particular level to achieve 30% reduction in the light output. On the basis of the above measurements, it was concluded that the Lumen IQ unit was performing as desired and the power and the light measurements.

Placement of markers and field sensors - Markers were placed at a distance of 5 feet from the base of the pole and the field sensor is placed in the centre of the marker for each of the measurement. This is depicted in the Figure below. It represents the top view of the set-up.

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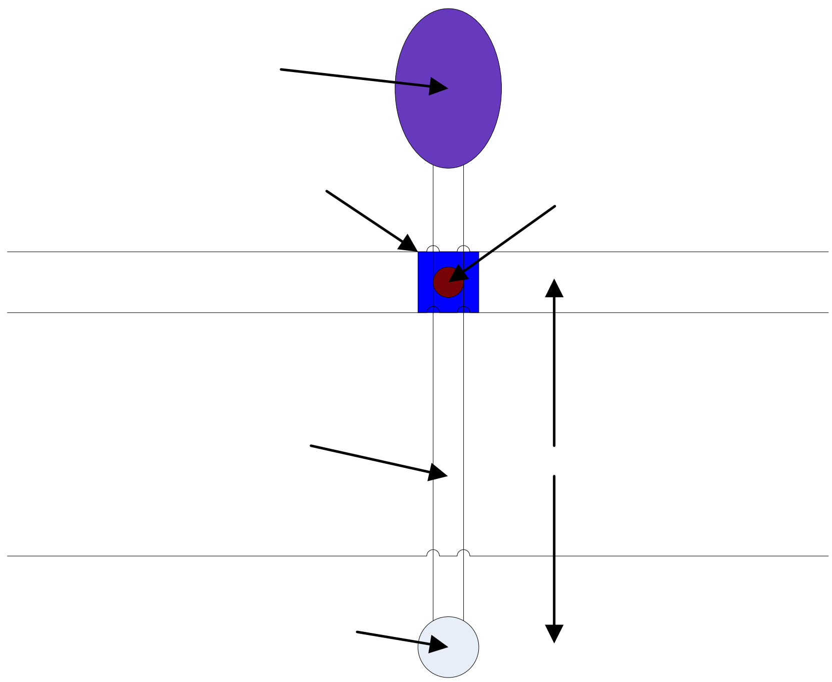

Figure 12 – Placement of Field Sensor

7.8 Measurement of Project Success

As a demonstration project, numerous measures are being developed to evaluate the success of the project, including the following.

- **Laboratory Testing.** This portion of the project is currently complete as briefly described in this paper. Under laboratory conditions the Lumen IQ appears to meet the performance requirements needed for field installation.

- **Field Testing.** Illuminance measurements under full power and dimmed conditions will be made to determine the performance of the units under field conditions. The results of these measurements will be compared with expected calculated results, as well as the data gathered by the system indicating system performance as measured by the lamp sensor were undertaken and the system performed as designed. Results noted under 7.7 Field Testing.

- **Public Comment.** The public is being informed about the project, and public comments will be monitored for both positive and negative feedback. To date no negative comment has been received.

- **Agency Comment.** Agencies such as the RCMP, Ministry of Transportation, BC Hydro and City maintenance forces and others will be

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monitored and/or solicited for comments. To date no negative comment has been received.

- **Increase in Collisions**. Nighttime collision statistics for the demonstration project are being gathered and will be compared with collision statistics gathered during the project for the hours the luminaires are under dimming. No negative lighting impacts contributing to collisions have been noted.

7.9 Lessons Learned to Date

Listed below are lessons learned as part of this assignment.

- **Engineering expertise is needed in the application of dimming technology.** The application of dimming technology will require engineering expertise. Experienced roadway lighting consultants will be able to assist owners in choosing the sites best suited for the technology, including the following.

- **Development of Design Criteria.** The engineer would establish design criteria for the municipality or agency for the proper application of dimming in line with standard practice.

- **Inventory of Existing Facilities.** An inventory of existing facilities will be required including pole spacing, roadway classifications, pedestrian conflict levels, existing lighting levels and uniformities, configurations, etc.

- **Provide Calculations.** The engineer would provide calculations necessary to establish the applicability of dimming.

- **Development of Cost Benefit Analysis.** The engineer would assist the municipality or agency to develop and analyze the cost and benefits available.

- **Participation in Public Process.** The engineer would assist the owner in responding to public inquires and participate in other aspects of the public process.

- **Development of Options and Rationale for Replacement or Retrofit of Luminaires.** If existing luminaires are being retrofitted with the dimming technology, the engineer would establish criteria for evaluating where a new luminaire should be considered. Issues would be age and condition, cost-effectiveness, etc.

- **Verification and Testing.** The engineer would provide independent verification of the performance of the dimming system.

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- **Master Planning is Recommended to Optimize the Application of Dimming.** Because communities and roadway networks are complex, development of a dimming master plan is recommended. The master plan will define how dimming will be applied, and coordinate the retrofit of existing systems and new installations. In general, the application of dimming to new installations (new roadways or new lighting in conjunction with roadway improvements) should be prioritized to take advantage of energy savings, while retrofitting existing lighting may depend on a number of factors.

- **Agreement Between Owner and Utility Companies Will Be Required.** Because most street lighting in North America is unmetered, an agreement between the utility company and the owner will normally be required for the owner to receive the monetary benefit associated with dimming. The agreement should provide for the utility's acceptance of the Lumen IQ calculation of power consumed and utility company access to the metering aspects of the luminaire database for verification.

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