WSDOT LED Adaptive Roadway Lighting & Illumination Reform

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Each year WSDOT spends millions of dollars on illumination system repairs, preventative maintenance and utility costs. In addition, the ongoing preservation funding needed to perform life cycle replacement of these systems far surpasses current and projected funding. With thousands of miles of state owned roadways and intersections with and without illumination a more strategic approach to when, where and why to provide roadway illumination is needed.
WSDOT Illumination Inventory

• Total Illumination Systems = 3,100 \textit{(400 installed since 2005)}
• Total Individual Light Fixtures = 60,000
  – Cobra Heads = 47.5%
  – Sign Lights = 2.5%
  – Pole Top = 3%
  – Underdeck = 14%
  – Wall Mount = 2%
  – Shoe Box = 4%
  – High Mast = 3%
  – Tunnel = 24%

100% \[\text{These are estimates based on extrapolations from existing inventory data}\]
WSDOT Illumination System Inventory

Data from SiMMS and Roadside Features inventory Database
WSDOT - Preventative Maintenance Expenditures
Traffic Signals, Illumination and ITS (12 year total)

- $13.5 Million, 51%
- $5.5 Million, 21%
- $5 Million, 20%
- $2 Million, 8%

Total = $26.5 Million

- Signal, Ramp Meter, Flashing Beacon Systems
- Illumination System
- ITS System (CCTV, VMS, HAR, RWIS, Radio, Phone, HUBS, Exp Ln Gates, WIM)
- Electrical Services
WSDOT – Repair, Non-Preventative Maintenance & Electricity
Traffic Signals, Illumination and ITS (12 year total)

- $1 Million, 1%
- $23 Million, 19.5%
- $35 Million, 30%
- $58 Million, 49.5%

Total = $117 Million

- Signal, Ramp Meter, Flashing Beacon Systems
- Illumination System
- ITS System (CCTV, VMS, HAR, RWIS, Radio, Phone, HUBS, Exp Ln Gates, WIM)
- Electrical Services
WSDOT Illumination System - Life Cycle Cost Analysis

Assumptions
- 3,100 Existing Illumination Systems
- 50yr Life Cycle
- Average System Cost = $125k
- All Existing Systems need to be replaced in kind

Rough Approximations
- Replacement Cost for 3,100 Systems
  = $400 Million or $8 Million / Year

Current Backlog ??
WSDOT Annualized Illumination System - Life Cycle Cost

- Repair & Non-Preventative Maintenance = $1.0 Million
- Preventative Maintenance = $0.5 Million
- Electricity = $4.0 Million
- Annual Replacement Cost to maintain existing inventory on a 50yr Life Cycle = $8.0 Million

2015 - 2021 $13.5 Million / Year

Current Project Funding to Replace Existing Illumination Systems $16 Million or $2.7 Million / year

(Need is $8.0 Million / Year)

30% is Electricity
It is clear revenues will not meet our needs so we have to rethink how we do the things.

One of the things we wanted to explore was ways that we could reduce our electricity consumption and maintenance costs for our illumination systems.
WSDOT started evaluating Light Emitting Diode (LED) lighting products several years ago. In the beginning there was not an established way to compare LED luminaire fixtures to our standard High Pressure Sodium (HPS) luminaires because they were so new to the industry. WSDOT received LED submittals from a multitude of manufacturers, both new to the lighting industry and also very established lighting manufacturers. With the number of requests and the varying types of fixtures it became clear that WSDOT needed a set evaluation process.
WSDOT created an evaluation process that was a multi-step approach to use and approval. First the manufacturers had to submit the product technical information to the HQ Traffic office for review. If they passed this initial stage the manufacturer was required to provide the photometric data file for computer evaluation. After passing these two stages the manufacturer was invited to a hands on demonstration with their fixture, maintenance personnel, materials lab personnel, lighting designers, and HQ Traffic personnel. If the manufacturer passed the three previous stages then their product was approved for field testing and evaluation.
Out of the 75+ fixtures we evaluated, only 4 manufacturers fixtures met the lighting requirements and were ready for field testing and evaluation.

The next step was selecting an appropriate interchange where we could do field testing.
LED Adaptive Lighting - Project Overview
US 101 and Black Lake Boulevard Interchange - Olympia
Interchange Characteristics

• The project is 1.2 miles on US101, a limited access control facility, with 60 MPH speed limit located near the state capitol.
• This is a Single Point Urban Interchange, with two mainline lanes in each direction.
• The Westbound Off-ramp and Eastbound On-ramp are double lane ramps.
• The Westbound On-ramp and Eastbound Off-ramp are single lane ramps.
• All illumination is shoulder mounted 40’ metal poles with 16’ mast arms, with the poles located 16’ from the fog stripe.
• All existing luminaires are 310W High Pressure Sodium Luminaires.
• Only the luminaire fixtures are to be changed. No new poles are to be added.
• System required to meet or exceed existing light levels.
The current lighting requirements for this section of roadway would be:
Average-0.6fc
Minimum-0.2fc
Uniformity-4:1 Max

The existing 310watt HPS luminaires generated light levels ranging from:
EB Mainline
Average-0.82fc
Minimum-0.1fc
Uniformity-8.20:1

WB Off Ramp
Average-1.24fc
Minimum-0.4fc
Uniformity-3.10:1
We broke the interchange up into four quadrants and placed each manufacturer in a separate quadrant.

Two manufacturers had 21 fixtures and the other two had 23 fixtures.
The request was made to make the evaluation project an adaptive system that could have dimming capabilities and also be programmable and controllable by time of night.
We evaluated the accident history for the entire interchange. We paid particular attention to the two ramps with the highest volumes. We checked the traffic volumes to identify times of night when the lights were not needed.
Collision Analysis – Black Lake Blvd EB on Ramp to US 101

US 101 On-Ramp from Black Lake Blvd to US 101 Increasing Direction
Q1 36591 for Aug 2008-Jul 2013
Heatmap: All Collisions by Hour

No Collisions from 11pm to 5am in past 5 years

Heatmap: All Collisions by Hour

0.0-0.1
0.1-0.2
0.2-0.3
0.3-0.4
0.4-0.5
0.5-0.6
0.6-0.7

Milepost

0-1 1-2 2-3 3-4
Collision Analysis – US 101 WB Off Ramp to Black Lake Blvd

US 101 Off-Ramp to Blacklake Blvd from US 101 Decreasing Direction
R1 36598 for Aug 2008-Jul 2013
Heatmap: All Collisions by Hour

No Collisions from 11pm to 5am in past 5 years

Milepost

0-1  1-2  2-3  3-4

0.0-<0.1  0.1-<0.2  0.2-<0.3  0.3-<0.4  0.4-<0.5  0.5-<0.6  0.6-<0.7
Given the time constraints WSDOT opted to go with a Lighting Control manufacturer with an established history.

After looking at what was available on the market and what other agencies selected we chose Acuity Brands ROAM lighting control system.
Some of the reasons WSDOT selected ROAM was:

• Time constraints looking at all manufacturers.
• ROAM is a manufacturing partner to one of the fixtures selected.
• ROAM was a “proven” commodity to WSDOT considering California and Union Station installations.
• The programming and controlling options in ROAM.
• Options available in ROAM gave WSDOT a way to keep track of the luminaire installation information and operating characteristics of each luminaire, unlike when we dig our signal system changeover to LED.
• Tracks the “operational health” of the system through System Diagnostics; Voltage and Power usage history per light
• Provides secure remote access for WSDOT Traffic Management Center for emergency
We went back to the four selected manufacturers and gave them our new requirements:

• 480V system.
• The luminaire had to be compatible with the ROAM system.
• Everything would be controlled off of one master photocell.
• All control and transformer equipment needed was required to be installed inside the luminaire fixture.
• Fixture and components required to have a warranty period of 10 years since our payback period was calculated at 12 years.
• Two of the manufacturers dropped out because they were unable to supply a 480V fixture and have the control and transformer equipment inside the luminaire fixture.
• After delaying the ordering process the third manufacturer backed out at the last minute for various reasons.
• This left WSDOT with one fixture: The American Electric Autobahn 2 fixture.
American Electric - Autobahn ATB2 LED Fixture

- 2 LED Drivers
- 1 Dimming Control Module (DCM)
- Installed 88 Lights on Existing Poles
LED Fixture and Node Installation
Remote Operating Asset Management (ROAM) Gateway Installation
Before / After Calculated Light Levels (Fc)

Objective: Average > 0.6 Fc; Minimum > 0.2Fc; Uniformity < 4:1

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<th>Location</th>
<th>310W HPS</th>
<th>185W LED</th>
<th>310W HPS</th>
<th>185W LED</th>
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<td>3.95 : 1</td>
<td>6.05 : 1</td>
<td>4.10 : 1</td>
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Project Installation and Cost Overview

- **88 Lights**, American Electric Autobahn Series ATB2 Luminaires: $90k
  
  Installation: $15k
  
  $105k

- Remote Operations Asset Management (ROAM)
  
  Materials, Installation, 1<sup>st</sup> Year Contract: $25k
  
  Ongoing Service Contract after 1st year: $2,400

  - **LED install**: 2 different 2 person Crews with a Bucket Truck, 4 days
  
  - **ROAM Nodes / Asset Management Data Capture**: 2 different 2 person Crews with a Bucket Truck, 4 days

  - **ROAM Operations and Installation Training**: 1 day in shop + 1 Day Field Engineer Support
Existing HPS - looking East
Existing HPS - looking West
After LED Install – Looking East
After LED Install – Looking West
ROAM Adaptive Lighting Overview

US 101 Black lake Blvd LED Adaptive Lighting Pilot Project

- 100% Lumen output = 187 watts

- During all hours of operation, all lights are dimmed to 70% lumen output (137 watts), which aligns with the "end of life" design standard. Each year the lumen output will increase by 2% (Year 1 = 70%, Year 2 = 72%, etc.) in order to ensure design standards are met throughout the life of the LED lights.

- At 10:59 pm, the 64 Additional Illumination Lights being turned off at 11pm will be dimmed to 15% lumen output (50 watts) for 1 minute to ease the transition to turning off.

- TMC can turn lights on remotely

- Installed 88 Lights on Existing Poles

Basic Illumination - Lights are on all night from dusk until dawn (24 lights total)

Additional Illumination - Lights are turned off from 11pm to 5am (64 lights total)
## BL Bvld - Calculated Power Savings

### HPS (Before Condition) Power Consumption

\[
\text{Power Consumption} = 88 \text{Lights} \times 387 \text{Watts/light} / 1000 \text{Watts/KWH} \times 13 \text{Hours/day} \times 0.10 / \text{KWH} = \$44.27/\text{day}
\]

Total = $44.27/day or $16,158.55/year

### LED (After Condition) Power Consumption

\[
\text{Power Consumption} = 26 \text{Lights} \times 138 \text{Watts/Light} / 1000 \text{Watts/KWH} \times 13 \text{Hours/day} \times 0.10 / \text{KWH} = \$4.66/\text{day}
\]

62 \text{Lights} \times 138 \text{Watts/Light} / 1000 \text{Watts/KWH} \times 7 \text{Hours/day} \times 0.10 / \text{KWH} = \$5.99/\text{day}

### Gateway Power Consumption

\[
\text{Power Consumption} = 1 \text{gateway} \times 10 \text{Watts/gateway} / 1000 \text{Watts/KWH} \times 24 \text{Hours/day} \times 0.10 / \text{KWH} = \$0.02/\text{day}
\]

### Nodes and Dimming Control Modules Power Consumption

\[
\text{Power Consumption} = 26 \text{Nodes} \times 2 \text{Watts/Node} / 1000 \text{Watts/KWH} \times 13 \text{Hours/day} \times 0.10 / \text{KWH} = \$0.07/\text{day}
\]

62 \text{Nodes} \times 2 \text{Watts/Node} / 1000 \text{Watts/KWH} \times 7 \text{Hours/day} \times 0.10 / \text{KWH} = \$0.09/\text{day}

Total = $10.83/day or $3,952.95/year

**75.5% Reduction ~ $12,205.60/year**
Actual Power Savings

After HPS to LED Conversion
51.5%

After Dimming and On / Off Operation by Time of Day
73.9%
Projected 15 year Maintenance and Operations Life Cycle Cost Savings

Save > $75,000 Maintenance & Ops

Save 1.7 million kwh of electricity

Analysis Included the following costs

• Initial Installation (Materials and Labor)

• Preventative Maintenance
  – 4 year Re-Lamp for HPS
  – Cleaning every 7.5 years for LED

• Operating Costs
  – Utility (Power) for all system components
  – Ongoing ROAM Service Agreement
Phase 2 - LED Adaptive Lighting
US101 & Copper Point Rd Interchange Olympia

Added 70 American Electric Autobahn ATB2 LED Fixtures to the existing System
• 60 at 480V
• 10 at 240V
Phase 2 - LED Adaptive Lighting
US101 & Copper Point Rd Interchange Olympia

$77k for LED Fixtures and Nodes
4 Days to install
Installed Fixtures and Nodes at same time

- Basic Illumination – Lights are on all night from dusk until dawn
- Additional Illumination – Lights are turned off from 11:00pm to 5:00am
Collision Analysis – Eastbound US 101

US 101 From Evergreen Pkwy to I-5 I/C (MP 364.07 - 367.41) for Aug 2008-Jul 2013
Heatmap: All Collisions, Mainline Increasing Direction by Hour

No Collisions from 11pm to 5am in past 5 years

Milepost
0-2  2-4  4-6  6-8  8-10  10-12  12-14  14-16  16-18  18-20  20-21
Collision Analysis – Westbound US 101

US 101 From Evergreen Pkwy to I-5 I/C (MP 364.07-367.41) for Aug 2008-Jul 2013
Heatmap: All Collisions, Mainline Decreasing Direction by Hour

No Collisions from 11pm to 5am in past 5 years

Black Lake Blvd

Copper Point Rd

Milepost

0-1 1-2 2-3 3-4 4-5
Collision Analysis – Cooper Point Rd
EB On Ramp to US 101

US 101 On-Ramp from Cooper Point Rd to US 101 Increasing Direction
Q1 36668 for Aug 2008-Jul 2013
Heatmap: All Collisions by Hour

No Collisions from 11pm to 5am in past 5 years
Project Installation and Cost Overview

- **70 Lights**, American Electric Autobahn Series ATB2 Luminaires: $72k
  Installation: $10k
  \[ \text{Total} = 82k \]

- Ongoing Service Contract after 1st year: $2,400

- **LED install**: 2 different 2 person Crews with a Bucket Truck, 4 days

- **ROAM Nodes / Asset Management Data Capture**: 2 person Crew with a Bucket Truck, 4 days
### CP - Calculated Power Savings

**HPS (Before Condition) Power Consumption**

\[
\text{68 Lights} \times \frac{387 \text{ Watts/light}}{1000 \text{ Watts/KWH}} \times 13 \text{ Hours/day} \times \frac{0.10}{\text{KWH}} = 34.21 \text{ /day}
\]

Total = $34.21/day or $12,486.94/year

**LED (After Condition) Power Consumption**

\[
\text{52 Lights} \times \frac{138 \text{ Watts/Light}}{1,000 \text{ Watts/KWH}} \times 13 \text{ hours/day} \times \frac{0.10}{\text{KWH}} = 9.33 \text{ /day}
\]

\[
\text{16 Lights} \times \frac{138 \text{ Watts/Light}}{1,000 \text{ Watts/KWH}} \times 7 \text{ hours/day} \times \frac{0.10}{\text{KWH}} = 1.55 \text{ /day}
\]

**Nodes and Dimming Control Modules Power consumption**

\[
\text{52 Nodes} \times \frac{2 \text{ Watts/Node}}{1,000 \text{ Watts/KWH}} \times 13 \text{ hours/day} \times \frac{0.10}{\text{KWH}} = 0.14 \text{ /day}
\]

\[
\text{16 Nodes} \times \frac{2 \text{ Watts/Node}}{1,000 \text{ Watts/KWH}} \times 7 \text{ hours/day} \times \frac{0.10}{\text{KWH}} = 0.02 \text{ /day}
\]

Total = $11.04/day or $4,029.60/year

**67.7% Reduction ~ $8,457.34/year**
Lessons Learned

Maintenance has been to the project about a dozen times trouble shooting issues.

- Approximately 12 poles repeatedly blowing fuses.
  - High inrush current > 100 AMPS, switched to 20amp slow blow fuses
- 1 transformer had to be replaced.
- 1 bad driver in a fixture, works at half power.
- 1 bad fixture, keeps shorting out & blowing fuses.
- 13 Nodes would not connect.
- Several fixtures were delivered with wiring issues (Pinched, chaffed, bad insulation)
Lessons Learned

• Order Spares – Fixtures and Control Nodes.
• Polarity of the circuit appears to make a difference – in both the head and node.
• Use slow blow fuses due to high inrush current
• LED fixtures are evolving rapidly so expect some out of the box failures.
• Issues with using one main photocell and communication with the nodes. Also adds another step in maintenance trouble shooting the system, they have to log in to ROAM and turn all the lights on in addition to flipping the test bypass switch.
• Test to make sure your control system will work will your selected luminaire.
ROAM Operations & Asset Tracking

https://ww2.roamportal.net/
**ROAM System Diagnostics**

**Wire Theft – WB on Ramp**
ROAM Power Usage History Per Light

- Full Lumen Output
- Dimming (70% Lumen Output)
### ROAM Burn Hour Report for US 101 & Black Lake

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<tr>
<th>Date Created</th>
<th>Device ID</th>
<th>Mac ID</th>
<th>DCM ID</th>
<th>Latitude</th>
<th>Longitude</th>
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<th>Pole Type</th>
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<th>Fixture Type</th>
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<td>118.75</td>
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**Note:** The table shows the burn hours and KWH usage for different lamp wattages and types. The data is cumulative and reflects the number of hours and energy consumed by the lamps. The total KWH hours are critical for energy management and planning.
For more information on the US 101 Adaptive LED Lighting Project and Illumination Reform
Please contact:

Keith Calais                              Ted Bailey
360-705-6986                              Or                              360-705-7286

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WSDOT Illumination Design Standards: www.wsdot.wa.gov/Design/Traffic

LED Pilot Project: www.wsdot.wa.gov/Design/Traffic/Electrical/LEDPilotProject