Washington State DOT

John Milton

Peer Exchange - Integrating Risk Management in Transportation Asset Management Programs

Illumination – Asset Opportunities and Risk

WSDOTs journey on rethinking why we light

John Milton, Ph.D. PE

Director - Quality Assurance and Transportation System Safety

Washington State Department of Transportation

Lynn Peterson

Secretary of Transportation

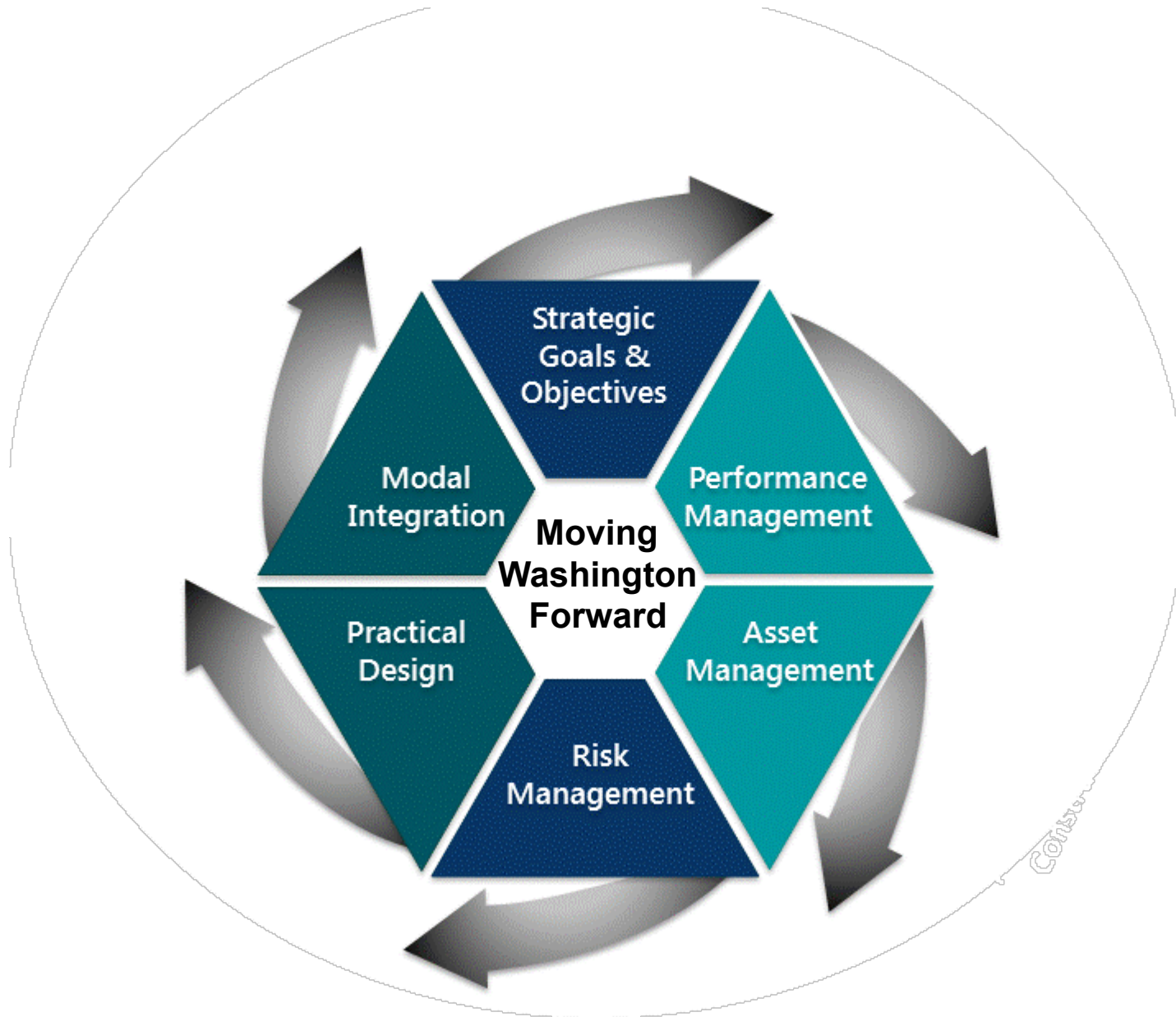**15th COTA International Conference of Transportation Professionals**
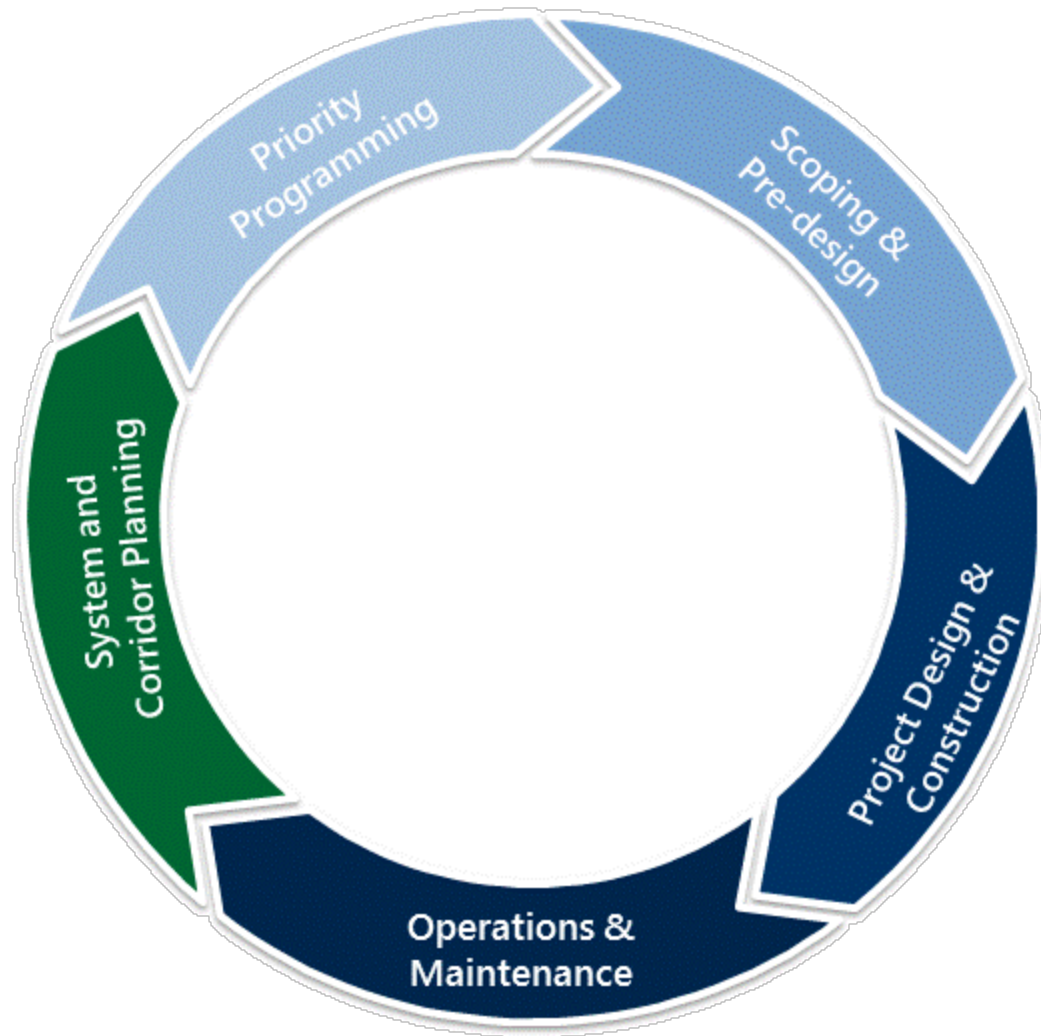
August 25, 2015
Minneapolis, Minnesota

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Main Points

1. Setting the stage
2. Illumination – ***Rethinking why we light***
   – Performance of lighting as an asset
   – Crash reduction research & incorporating predictive modeling into lighting decision-making
3. Case Study: LED Adaptive Lighting Pilot
4. Looking forward – What's Next?

Asset-Risk management triangle expanded

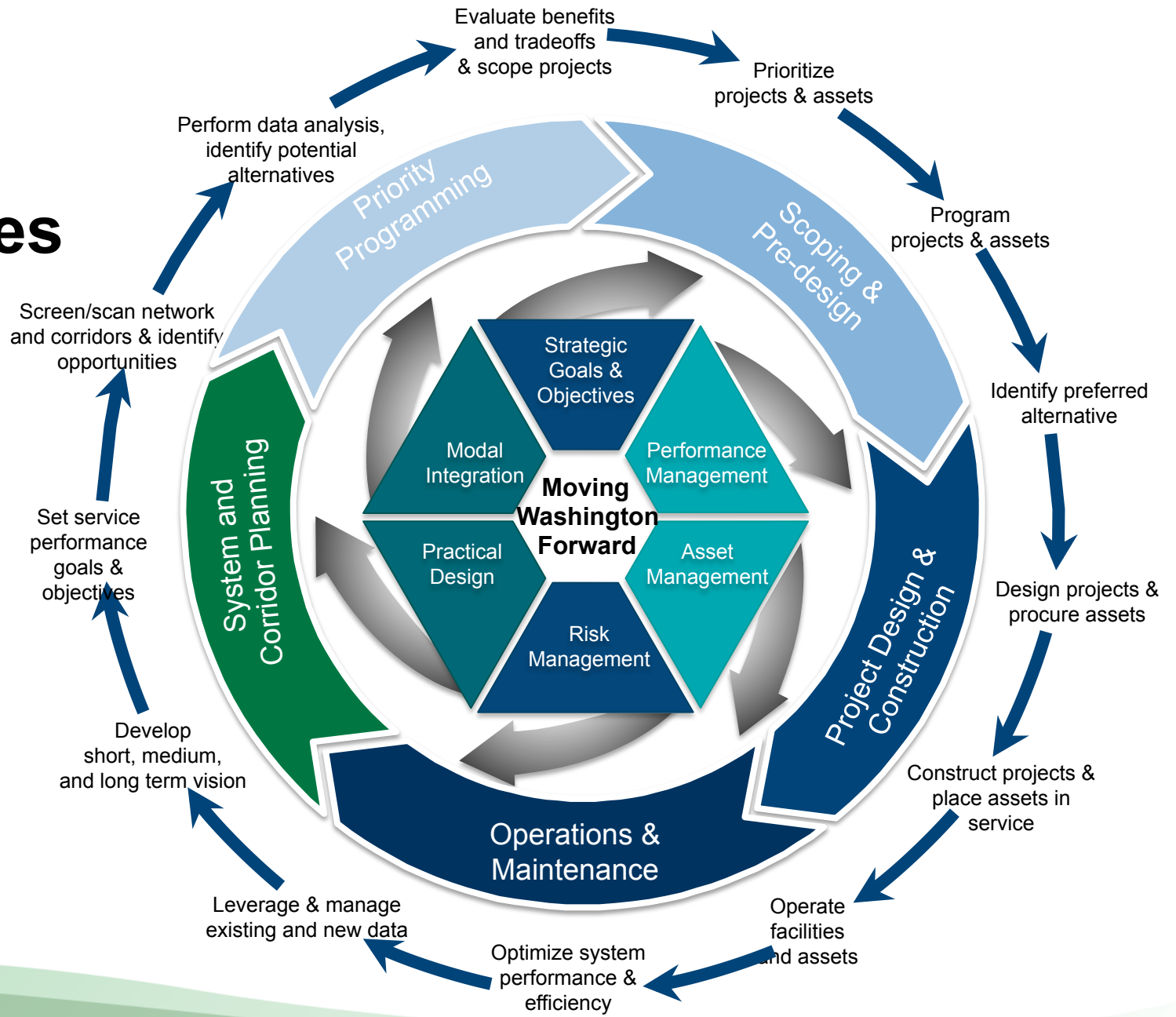The cycle includes: Priority Programming, Scoping & Pre-design, Project Design & Construction, Operations & Maintenance, System and Corridor Planning

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Asset-Risk choice alignment with agency policy

Asset-Risk activities

Priority Programming

Perform data analysis, identify potential alternatives

Evaluate benefits and tradeoffs & scope projects

Prioritize projects & assets

Scoping & Pre-design

Program projects & assets

Identify preferred alternative

Screen/scan network and corridors & identify opportunities

Set service performance goals & objectives

System and Corridor Planning

Develop short, medium, and long term vision

Leverage & manage existing and new data

Project Design & Construction

Design projects & procure assets

Construct projects & place assets in service

Operate facilities and assets

Operations & Maintenance

Optimize system performance & efficiency

Moving Washington Forward

- Strategic Goals & Objectives
- Performance Management
- Asset Management
- Risk Management
- Practical Design
- Modal Integration

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Source: Milton and Van Schalkwyk (April 2014 v.7)

SETTING THE STAGE

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The nature of DOT business approach is changing

- Transitioning from capital capacity projects to operating and maintaining the current system
- Focused on "multimodal context based" solutions
- Targeted to address multiple performance aspects of an asset.
- Carbon Pollution Reduction & Clean Energy Action
    - http://governor.wa.gov/office/execorders/documents/14-04.pdf
- WSDOT Executive Order 1090.00, " Moving Washington Forward: Practical Solutions" (August 20th, 2014):
    - Use of quantitative methods including the Highway Safety Manual (HSM)
    - "Substantive versus nominal safety improvements."
    - Least cost planning
    - Practical design

WSDOT Illumination Systems 2014

- Existing systems: 3,100 *(400 installed since 2005)*

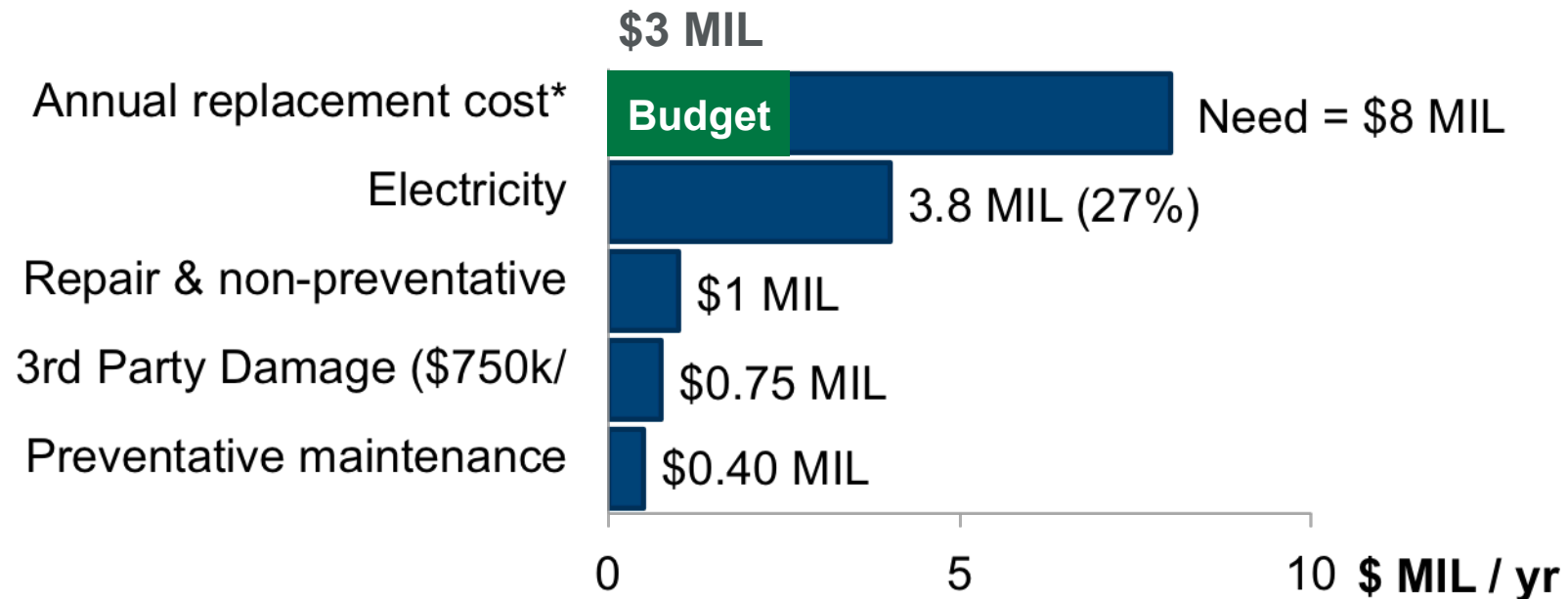- Roadway light fixtures: 60,000
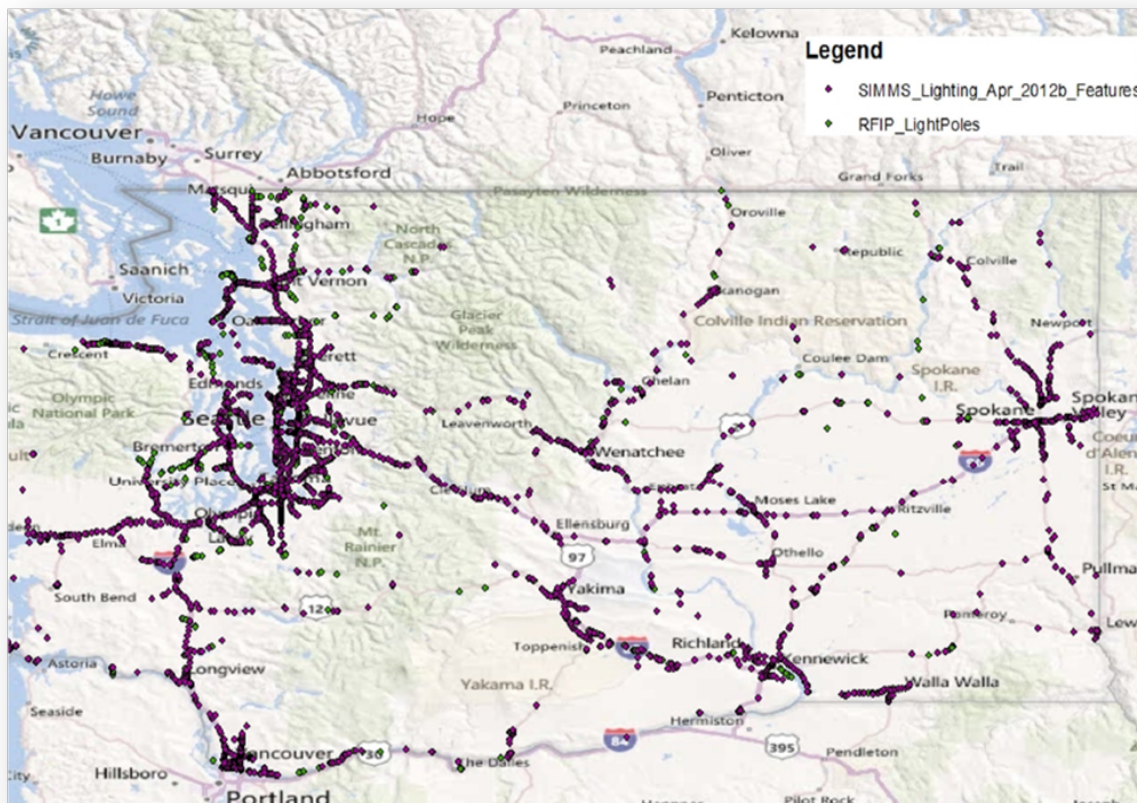
- Cobra Heads 48%
- Sign Lights   2%
- Pole Top   3%
- Underdeck   14%
- Wall Mount   2%
- Shoe Box   4%
- High Mast   3%
- Tunnel   <u>24%</u>
    100%

Source: SiMMS & Roadside Features Inventory Program (RFIP) database

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WSDOT Illumination Systems

Budget does not fund annualized life cycle cost

$13.95 MIL/yr

$3 MIL

Annual replacement cost*	Budget / Need = $8 MIL
Electricity	3.8 MIL (27%)
Repair & non-preventative	$1 MIL
3rd Party Damage ($750k/	$0.75 MIL
Preventative maintenance	$0.40 MIL

0   5   10 $ MIL / yr

OPTIMIZING ASSET PERFORMANCE – CHALLENGING ASSUMPTIONS

Why do we have so much lighting?

1974 - 1995

26.8 BCR →

	HIGHWAY SAFETY IMPROVEMENTS WITH THE HIGHEST BENEFIT-COST RATIOS 1974-1995	
Rank	**Improvement Description**	**Benefit-Cost Ratio**
1	Illumination	26.8
2	Upgrade Median Barrier	22.6
3	Traffic Signs	22.4
4	Relocated/Breakaway Utility Poles	17.7
5	Remove Obstacles	10.7
6	New Traffic Signals	8.5
7	Impact Attenuators	8
8	New Median Barrier	7.6
9	Upgrade Guardrail	7.5
10	Upgrade Traffic Signals	7.4
11	Upgrade Bridge Rail	6.9
12	Improve Sight Distance	6.1
13	Median for Traffic Separation	6.1
14	Groove Pavement for Skid	5.8
15	Improve Minor Stricture	5.3
16	Turning Lanes and Channelization	4.5
17	New RR Crossing Gates	3.4
18	New RR Crossing Flashing Lights	3.1
19	Pavement Markings and Delineation	3.1
20	New RR Crossing Lights & Gates	2.9

Federal Highway Administration (1996). The 1996 Annual Report on Highway Safety Improvement Programs. Publication No. FHWA-SA-96-040; referenced in http://onlinepubs.trb.org/onlinepubs/nchrp/docs/NCHRP05-19_LitReview.pdf

Intended Outcomes

Goal - Develop a <u>risk-based approach</u> that considers roadway <u>lighting performance and risks</u> to achieve and optimal level of lighting without significant impacts to **crash** and mobility <u>strategic goals and objectives</u>

- **Reduce Life Cycle Cost (Asset Performance)**
    - Provide light only when needed (existing and future systems)
    - Then, Convert to high – efficiency LED technology

- **Sustainable and Clean Technology (Asset Impacts)**

- **Recognize advancements in safety analysis**

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Reduce fatal and serious injuries to zero in 2030

Target ZERO

Where should we focus?

System performance: main characteristics

System wide priority: at the right place & time

Distribution across users and facility types

What should we focus on?

Crash characteristics
- Users & vehicles; severity; collision types; time of day

Context
- Physical environment; vehicle operating speeds & volumes; land use & generators

Contributing factors
- Human: Errors, Risky behavior
- Environment: Weather, geometry
- Vehicle: Type, size,

What should we do to maximize our investment?

Goals: reduce fatal & serious injury risk; and/or reduce injury severity

Cost-effectiveness

Time scale (short, medium or long-range)

Design/ project development/ activity implementation

Tradeoff decisions with other policy goal areas
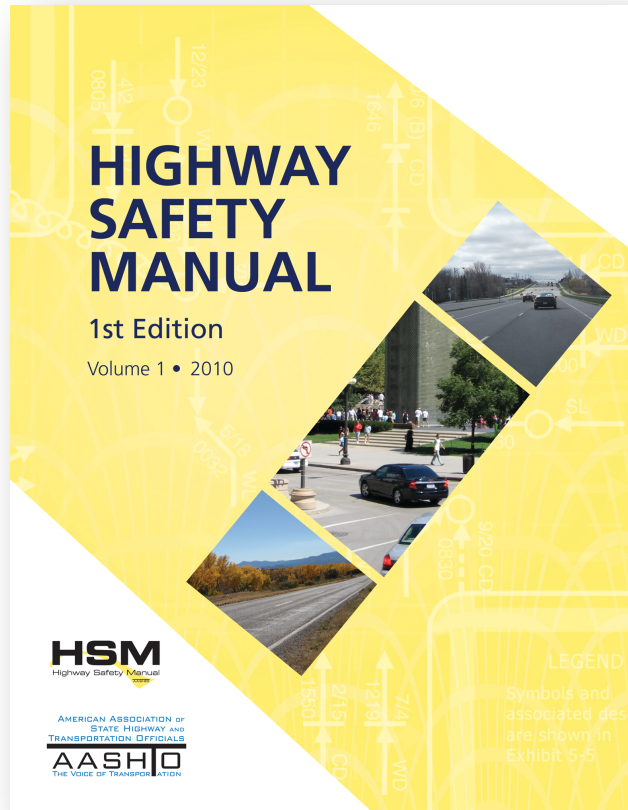
Did it work?

Performance (impact): system, corridors, locations / projects, treatment types
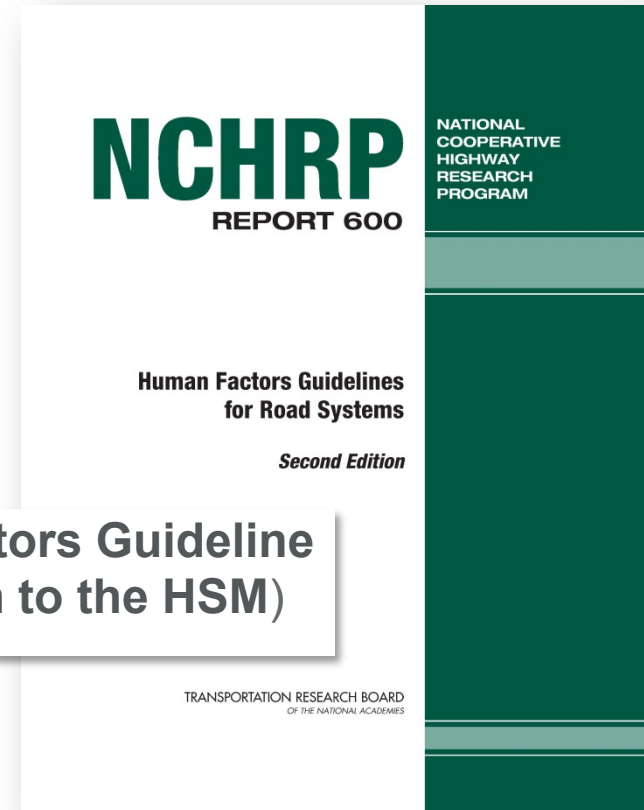
Evaluation
- Before-after analysis
- CMF development
- Policy redevelopment
- System modification

Advancements in the analysis of safety

Predictive methods in Part C of the Highway Safety Manual

Human Factors Guideline (companion to the HSM)

AASHTOWare SafetyAnalyst network screening (using Part B methods of the Highway Safety Manual)

Domestic & International Illumination Research Review

- >300 papers & reports (1960's – 2014)
- Rigor of research methods evaluated based on:

Experimental design
- Site selection: were the sites similar in characteristics or different? What criteria were used?
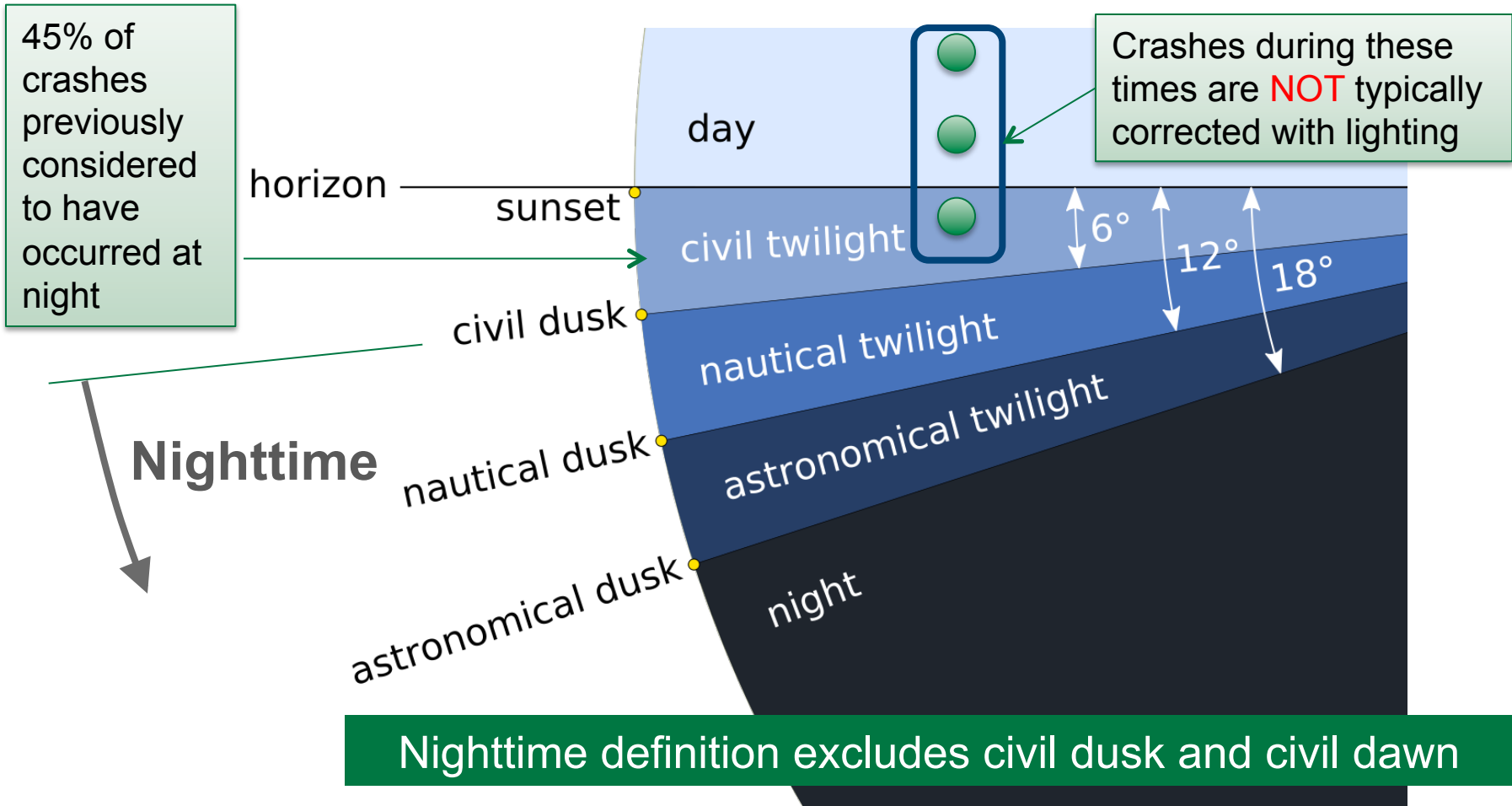- Which crashes were included in the analysis? How were they identified?

Datasets
- Sample size: how many crashes were analyzed and what are the confidence levels for the results?
- What site characteristics were collected and included in the analysis?

Analysis method
- Is the method science-based and valid for crash analysis?
- Are the assumptions scientifically sound?
- Did the method account for differences in roadway characteristics that we know have impact on crash performance?
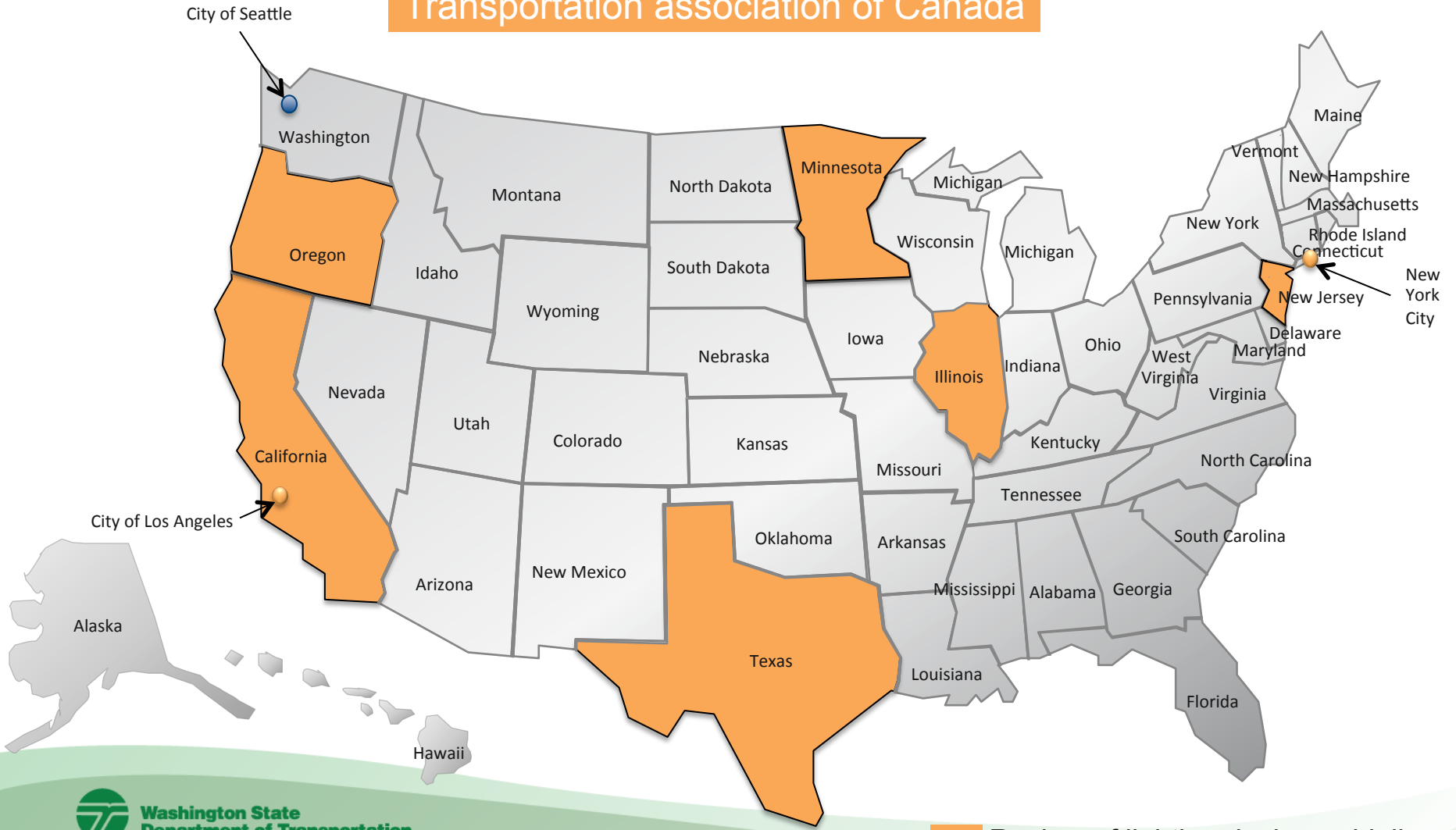
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How do we define nighttime?

45% of crashes previously considered to have occurred at night

Crashes during these times are NOT typically corrected with lighting

day

horizon

sunset

civil twilight

6°

12°

18°

civil dusk

nautical twilight

Nighttime

nautical dusk

astronomical twilight

astronomical dusk

night

Nighttime definition excludes civil dusk and civil dawn

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Domestic & International Illumination Research Review

- Published research from 2010 – 2014
  - **In general terms only research conducted after 2010 included the consideration of other factors** besides illumination that may have impacted the crash reduction performance.
    - Geometry / Channelization
    - Speed
    - Traffic Volume
    - Congestion
    - Pavement Markings
    - Access Density
- Published research prior to 2010
  - Before / After Crash analysis is suspect to *"apples and oranges"* type issues

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Domestic State Design Manual Review

City of Seattle

Review of lighting design guidelines

How are states deciding on illumination?

In General Terms

Typical Triggers lighting

1. More Light and more uniform light are better

2. Night time congestion is a trigger for continuous illumination

3. Complex roadway geometry (closely spaced interchanges, weaving)

4. High night time ADT

5. Urban area / nearby commercial or ambient lighting

6. Assumption that night crashes are always mitigated with illumination

   • **Use of day / night crash frequencies in crash reduction warrants**

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Tools & analysis methods –
WSDOT is using random parameter models

Proven approach to consider **multiple factors at the same time** – get closer to comparing 'apples to apples', and allow for differences among the similar locations (other than those modeled), to be quantified.

Example of Washington State-specific research recently published in Accident Analysis & Prevention:

Accident Analysis & Prevention

Volume 59, October 2013, Pages 309–318

ELSEVIER

Random parameter models of interstate crash frequencies by severity, number of vehicles involved, collision and location type

Narayan Venkataraman[a, 1] ✉, Gudmundur F. Ulfarsson[a] ⚷ ✉, Venky N. Shankar[b, 2] ✉

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Crash analysis approach to evaluate changes in roadway lighting on the WA state system

- WSDOT's national crash reduction research team is **currently developing random parameter crash prediction models**. These models will be the **basis for a data-driven & science-based method** to inform decisions about changes to existing roadway lighting on the state roadway system.

- The method focuses on the **impact of roadway lighting on the number and severity of motor vehicle crashes**, and particularly: dusk-to-dawn crashes and utility pole crashes (any time of day).

- **Factors included in the models** (using **5 yrs. of crash data**):

Geometry, volumes and urban/rural character	Roadway lighting
• Traffic volume • Number of lanes • Shoulder widths (left and right) • Horizontal curvature • Vertical curvature • Presence of interchange • Urban/rural character	• Median roadway lighting proportion • Right roadway lighting proportion • Both-side roadway lighting proportion • Point roadway lighting proportion • No roadway lighting proportion

WSDOT is challenging the preconceived notion that lighting saves the day…

- Deeply held beliefs:
  - Roadway lighting reduces crashes during **dawn and dusk** (civil twilight)
  - All nighttime crashes can be 'fixed' with roadway lighting
  - **The ratio of daytime vs nighttime crash rates is a reliable and science-based method** to estimate how many nighttime crashes to expect at a given location
  - During congested conditions, adding roadway lighting reduces crashes
  - **Nighttime crash rates is a reliable and science-based method** to identify locations for lighting
  - **Just a few years of crash histor**y are needed to identify locations where roadway lighting will reduce crashes
  - Roadway lighting reduces crashes at the daytime
  - **More uniform light is better**
  - **Roadway complexity is always a trigger** for illumination

WSDOT is challenging the preconceived notion that lighting saves the day…

A new perspective on some deeply held beliefs:

- ~~Roadway lighting reduces crashes during **dawn and dusk** (civil twilight)~~ crash reduction is unlikely during civil twilight because there is still sufficient small target visibility at that time
- ~~All nighttime crashes can be 'fixed' with roadway lighting~~ – only a subset of nighttime crashes may be 'correctable' with illumination
- ~~The **ratio of daytime vs nighttime crash rates** is a reliable and science-based method to estimate how many nighttime crashes to expect at a given location~~ – *scientific basis uncertain*
- ~~During congested conditions, adding roadway lighting reduces crashes~~ – no scientific basis found & vehicle headlights add lighting during nighttime congested conditions
- ~~**Nighttime crash rates is a reliable and science-based method** to identify locations for lighting~~ – a crash rate is not a reliable method for identifying potential locations for lighting
- ~~**Just a few years of crash history** are needed to identify locations where roadway lighting will reduce crashes~~ –crashes are random & our methods should account for the variation; the methods should also account simultaneously for other factors at the location that are likely to impact crash risk.
- ~~Roadway lighting reduces crashes at the daytime~~ – research review found no scientific basis for the assumption that lighting would reduce crashes during daytime (i.e. lighting conditions other than dusk to dawn)
- ~~**More Uniform Light is better** -~~ – *scientific basis uncertain*
- ~~**Roadway complexity is always a trigger** for illumination~~ - *scientific basis uncertain*

- **The cost of replacing lighting poles that are hit is large ($750k annually) & presence of poles create crash risk**

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# WSDOT Design Policy Changes – July 2014

In general terms:

- Illumination is either **required at specific locations all the time** or **added based on "Other" context**. (Cash Reduction, Pedestrian Security, Economic Vitality, etc.)

- For Crash Reduction based additional illumination a Crash Analysis is required.
  - 5 years crash history
  - Must have a B/C greater than 1
  - Must consider alternative lower cost counter measures first

- Use of LED and Adaptive Lighting are now approved

- Reduced uniformity requirements from 3:1 to 4:1

- Planning to remove the requirement for overhead sign lighting.

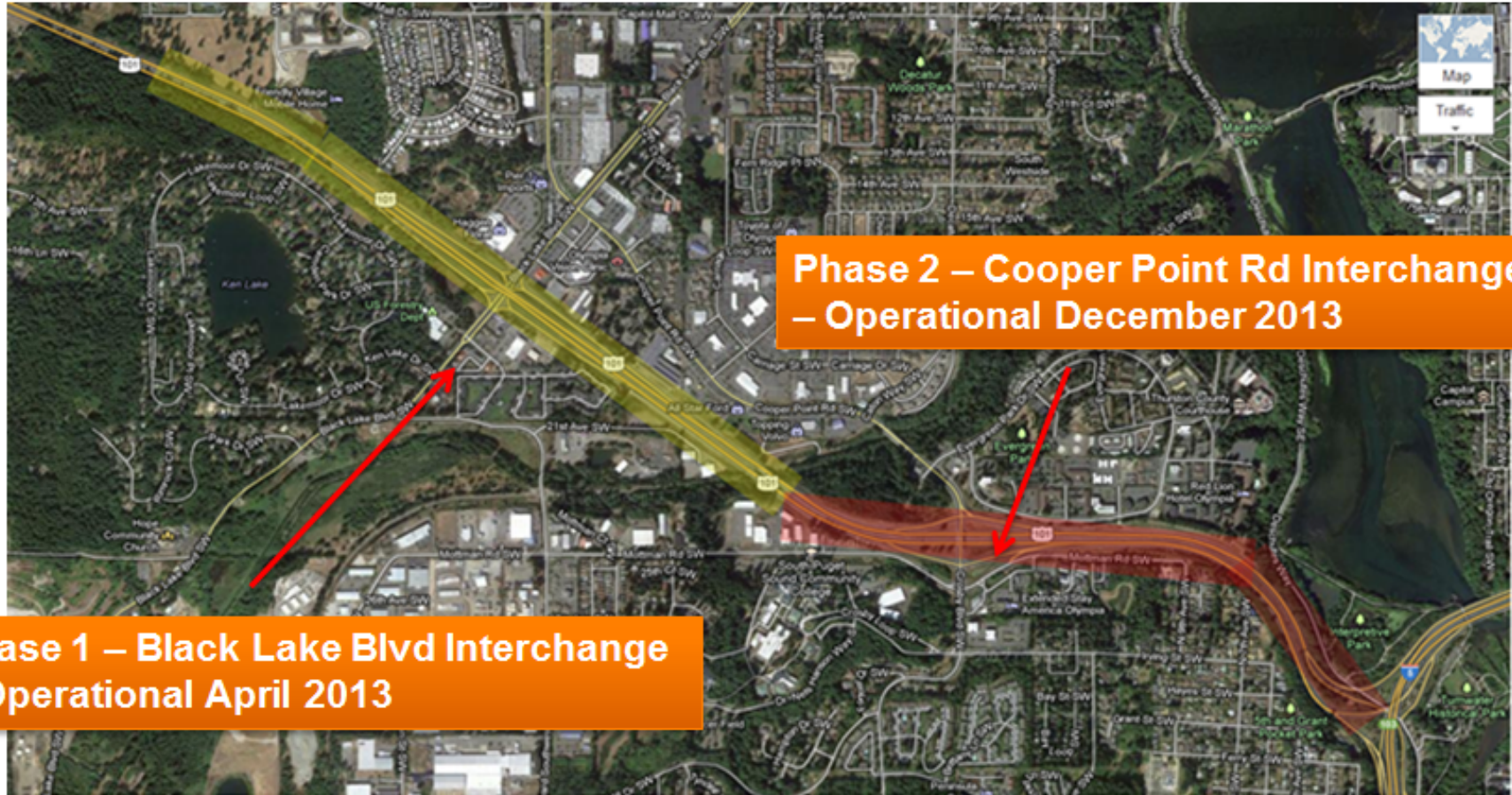# WSDOT Design Policy Changes – July 2014

In general terms:

Typical Required Illumination Design Areas – Looking forward.....

Signalized Intersections

28
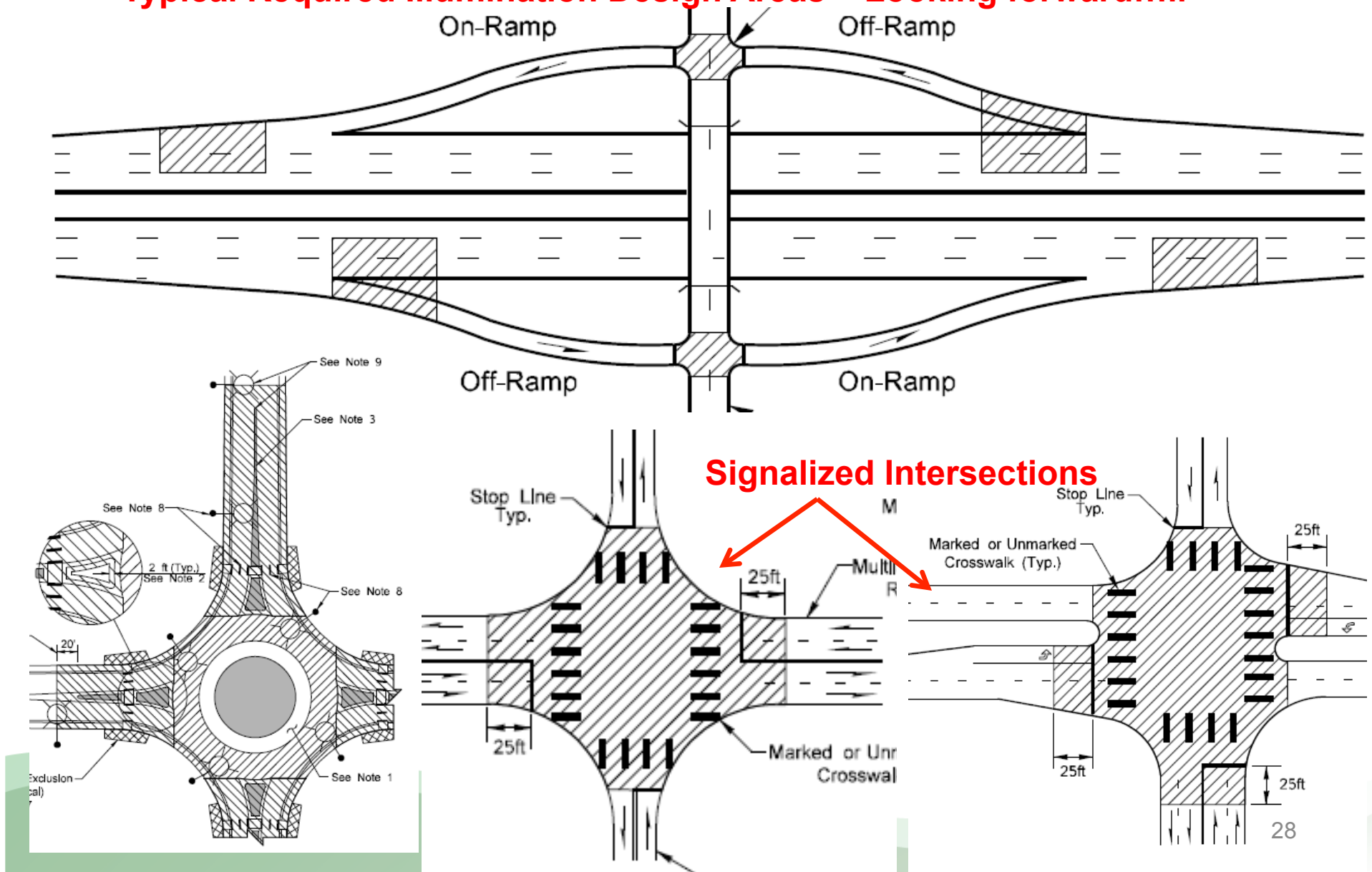
CASE STUDY: LED ADAPTIVE ROADWAY LIGHTING PILOT

LED Adaptive roadway lighting pilot (US 101, Olympia WA)

Phase 2 – Cooper Point Rd Interchange – Operational December 2013

Phase 1 – Black Lake Blvd Interchange – Operational April 2013

Crash 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

Black Lake Blvd

Cooper Point Rd

Milepost

Legend: 0-2 | 2-4 | 4-6 | 6-8 | 8-10 | 10-12 | 12-14 | 14-16 | 16-18 | 18-20 | 20-21

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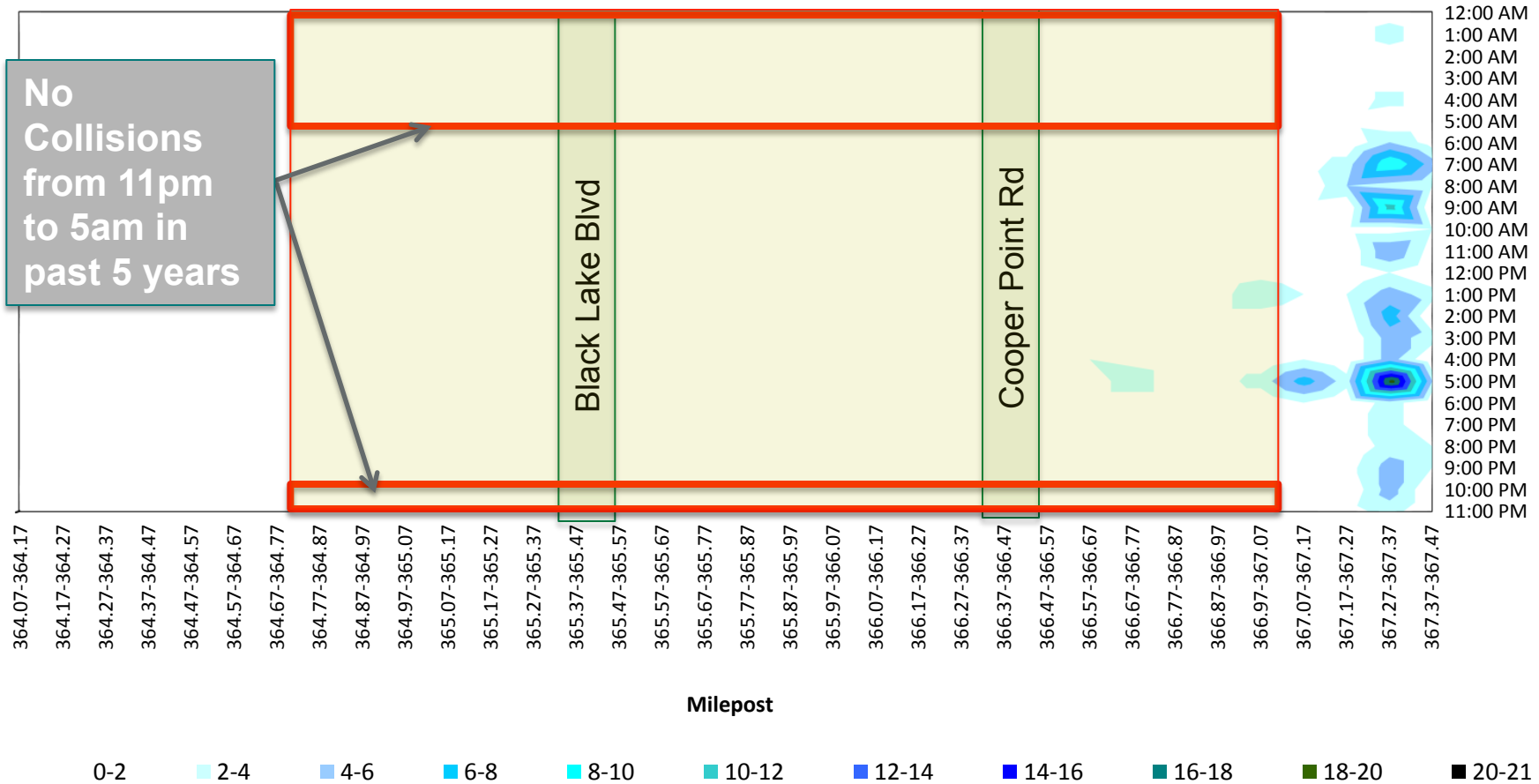
LED Adaptive System Installation
(US 101 & Black Lake Blvd Interchange)

LED Adaptive System Installation
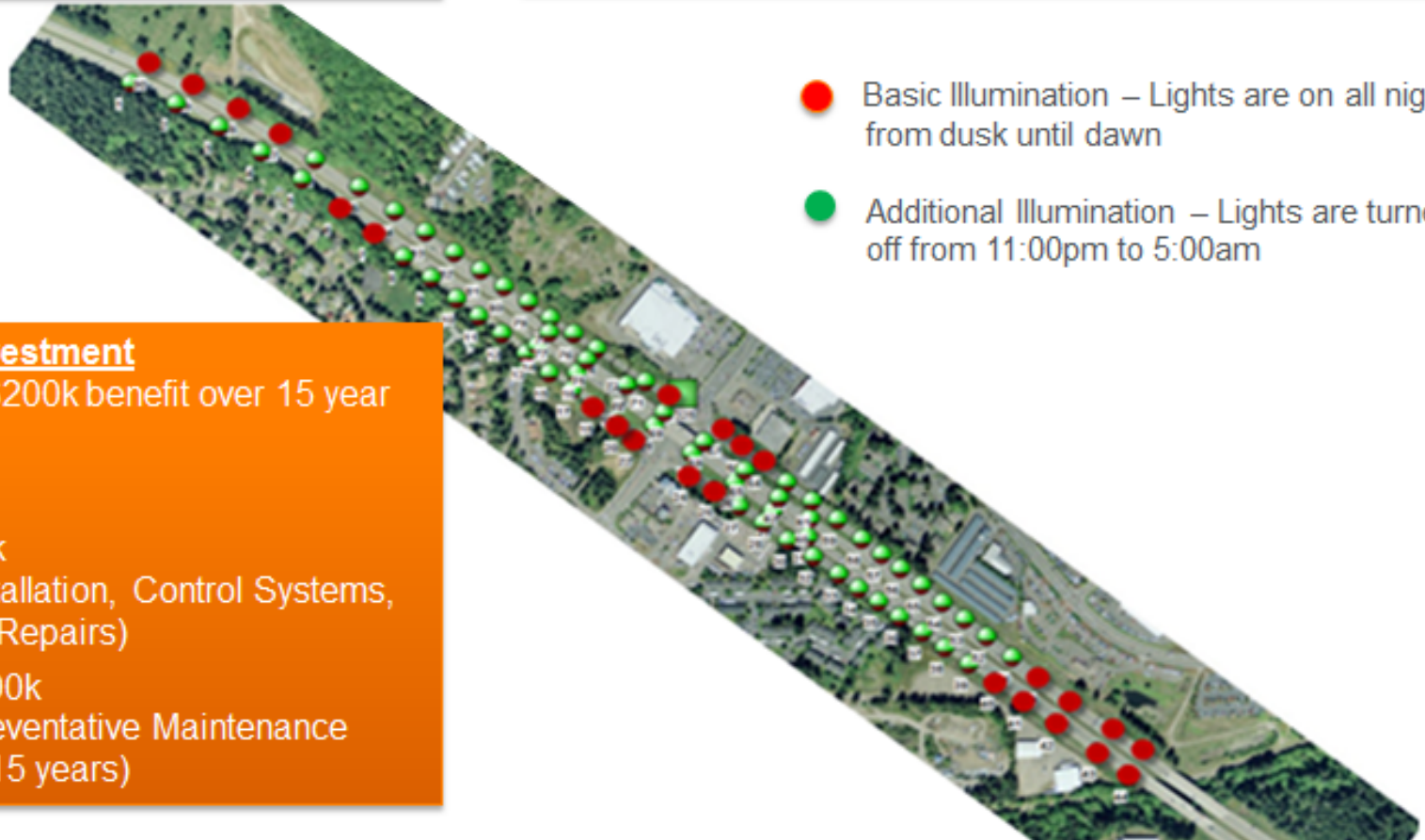# (US 101 & Black Lake Blvd Interchange)

LED Adaptive Lighting – Phase 1
US101 & Black Lake Blvd Interchange Olympia, WA

Installed 88 LED Lights in April 2013

- 74% energy reduction or 1.7 M kwh over 15 years
- 1,200 Metric Tons of Carbon Dioxide Equivalent

🔴 Basic Illumination – Lights are on all night from dusk until dawn

🟢 Additional Illumination – Lights are turned off from 11:00pm to 5:00am

Return on Investment
$174k Cost / $200k benefit over 15 year life cycle
= 13 Years

- Cost = $174k
(Materials, Installation, Control Systems, Maintenance, Repairs)

- Benefit = $200k
(Utility and Preventative Maintenance Savings over 15 years)

LED Adaptive Lighting – Phase 1
US101 & Black Lake Blvd Interchange Olympia, WA

US 101 in Olympia: Adaptive Roadway Lighting Pilot (Black Lake Blvd)

Before – HPS East View

After – LED East View

Before – HPS West View

After – LED West View

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(US 101 & Black Lake Blvd Interchange) – Phase 1
Before / After Calculated Light Levels (Fc)

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

Westbound Off Ramp

Priority Ramp		310W HPS	185W LED
	Average	1.24	0.84
	Maximum	2.4	1.6
	Minimum	0.4	0.3
Avg/Min (Uniformity Ratio)		3.10 : 1	2.80 : 1

Eastbound Off Ramp

		310W HPS	185W LED
	Average	1.23	0.86
	Maximum	2.5	1.7
	Minimum	0.3	0.2
Avg/Min (Uniformity Ratio)		**4.10 : 1**	**4.30 : 1**

Westbound Mainline

		310W HPS	185W LED
	Average	0.85	0.6
	Maximum	2.7	2
	Minimum	**0.1**	**0.1**
Avg/Min (Uniformity Ratio)		**8.50 : 1**	**6.00 : 1**

Eastbound Mainline

		310W HPS	185W LED
	Average	0.82	0.6
	Maximum	2.7	1.8
	Minimum	**0.1**	**0.1**
Avg/Min (Uniformity Ratio)		**8.20 : 1**	**6.00 : 1**

West Bound On Ramp

		310W HPS	185W LED
	Average	1.1	0.79
	Maximum	2.6	1.8
	Minimum	0.2	0.2
Avg/Min (Uniformity Ratio)		**5.50 : 1**	3.95 : 1

Eastbound On Ramp

Priority Ramp		310W HPS	185W LED
	Average	1.21	0.82
	Maximum	2.4	1.6
	Minimum	0.2	0.2
Avg/Min (Uniformity Ratio)		**6.05 : 1**	**4.10 : 1**

(US 101 & Black Lake Blvd Interchange) – Phase 1 Before / After Field Light Levels (Fc)

HPS Lights West Bound Mainline
1.65 Fc (Avg) / 0.15 Fc (Min) = 11 : 1
1.46 Fc (Avg) / 0.15 Fc (Min) = 10 : 1

HPS Lights East Bound Mainline
1.5 Fc (Avg) / 0.12 Fc (Min) = 12.5 : 1
1.6 Fc (Avg) / 0.10 Fc (Min) = 16 : 1

LED Lights West Bound Mainline
1.0 Fc (Avg) / 0.08 Fc (Min) = 12.5 : 1
0.83 Fc (Avg) / 0.08 Fc (Min) = 10 : 1

LED Lights East Bound Mainline
0.83 Fc (Avg) / 0.12 Fc (Min) = 7 : 1
1.0 Fc (Avg) / 0.12 Fc (Min) = 8 : 1

Source:
Dr. Ronald Gibbons,
Virginia Tech Transportation Institute
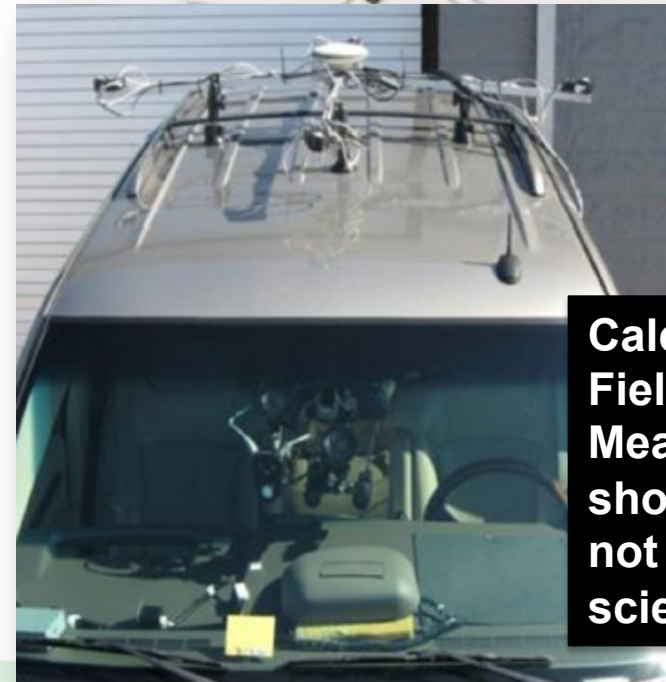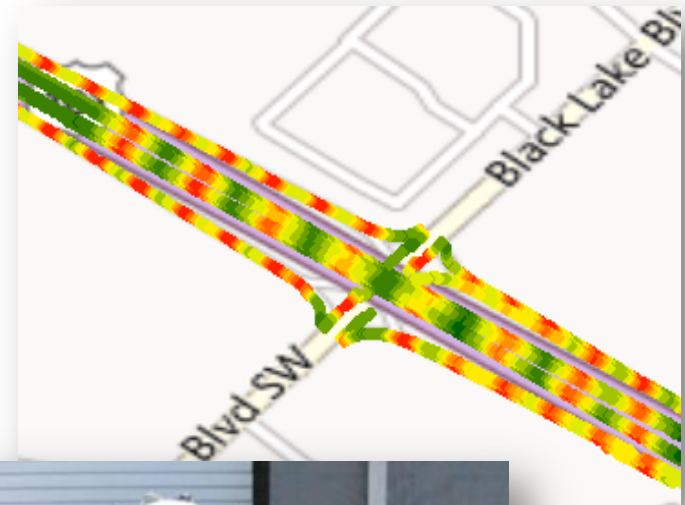
Calculated vs Field Measurements show this is not an exact science.

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LED Adaptive Lighting - Phase 2
US101 & Copper Point Rd Interchange Olympia

- 68% energy reduction or 1.3 M kwh over 15 years
- 900 Metric Tons of Carbon Dioxide Equivalent

Installed 70 LED Lights in December 2013

Return on Investment
$90k Cost / $145k benefit over 15 year life cycle = 9 Years

- Cost = $90k
(Materials, Installation, Maintenance, Repairs)

- Benefit = $145k
(Utility and Preventative Maintenance Savings over 15 years)

🔴 Basic Illumination – Lights are on all night from dusk until dawn
🟢 Additional Illumination – Lights are turned off from 11:00pm to 5:00am

LOOKING FORWARD WHAT'S NEXT?

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Illumination Reform

Looking Forward

- **Finishing crash analysis map** for all non-Interstate mainline roadways
  - Develop GIS Map indicating where lights are needed and where they can be removed (All Interstate and non-Interstate roadways)

- **Performance Contracting – Statewide Roadway Lighting Conversion / Removal / Adaptive Lighting Project**
  - $2M LED Roadway Lighting Conversion and Removal Project is underway using Energy Savings Performance Contracting

- **Additional Research**
  - SHRP2 Naturalistic Driving (Human Factors), $100k Federal Grant
  - Accelerated Innovation Deployment (AID) Demonstration Project, $1M Federal Grant

- Communication plan
  - Discussing conversion to LED technology and light removal projects

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Crash Analysis Map – Statewide Roadway Lighting Conversion / Removal / Adaptive Lighting Project
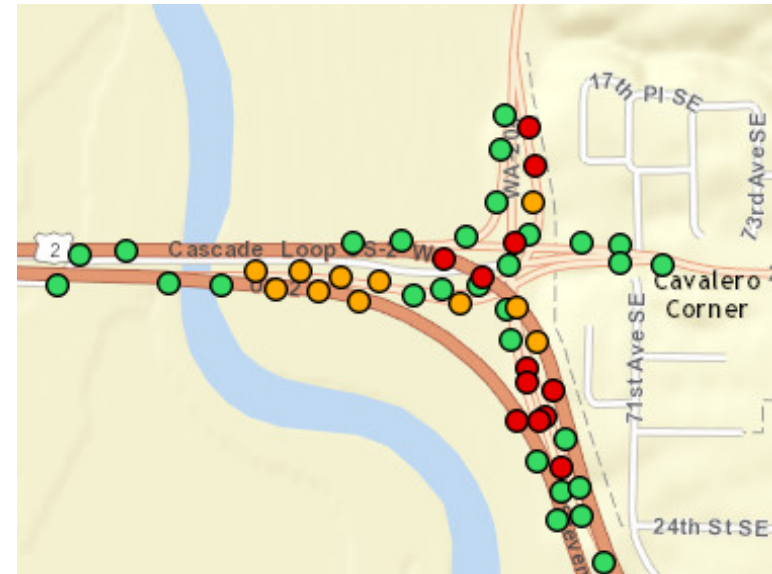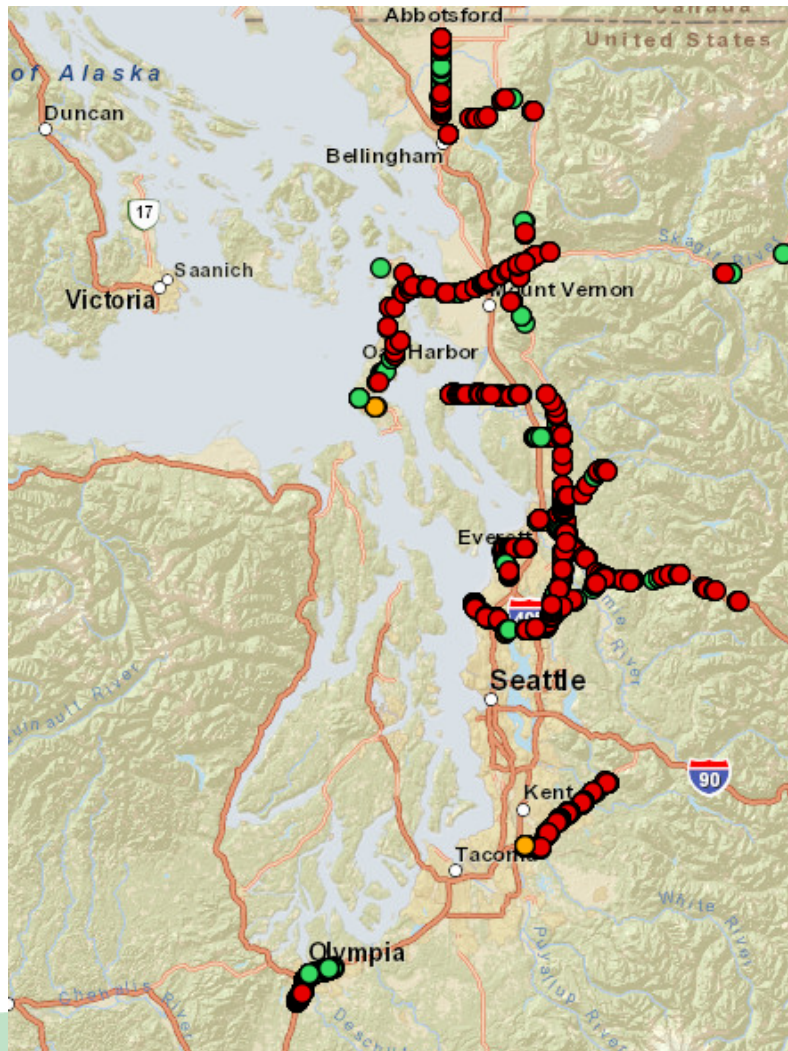
- ● LED Replacement
- ● Pole identified for removal
- ● Pole identified for removal (crash review recommended)

Under 23 U.S. Code § 409, safety data, reports, surveys, schedules, lists compiled or collected for the purpose of identifying, evaluating, or planning the safety enhancement of potential crash sites, hazardous roadway conditions, or railway-highway crossings are not subject to discovery or admitted into evidence in a Federal or State court proceeding or considered for other purposes in any action for damages arising from any occurrence at a location mentioned or addressed in such reports, surveys, schedules, lists, or data.

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Credits: WSDOT Illumination Reform and LED Adaptive Roadway Lighting

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