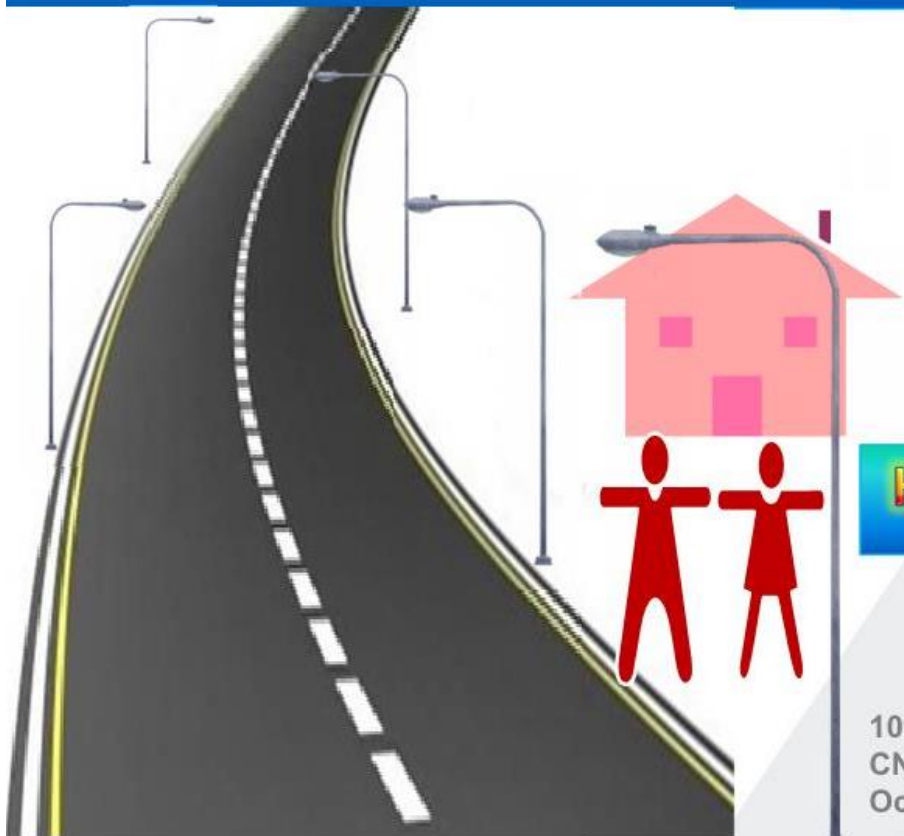




A Holistic Roadway Lighting Design Approach Makes a Vital Contribution to the Visibility, Operational Efficiency, Health and Safety of the Motorists and Public



Holistic Roadway Lighting Design

Uthayan Thurairajah

Toronto, Canada | October 19, 2015

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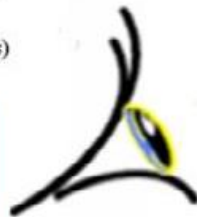
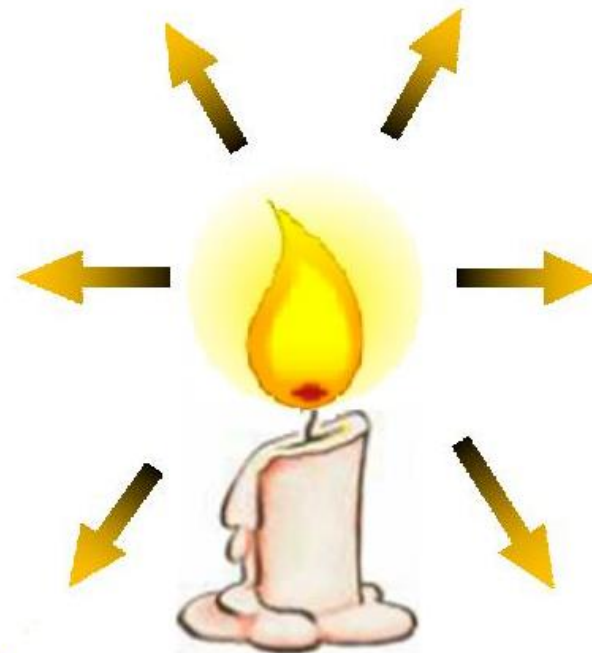
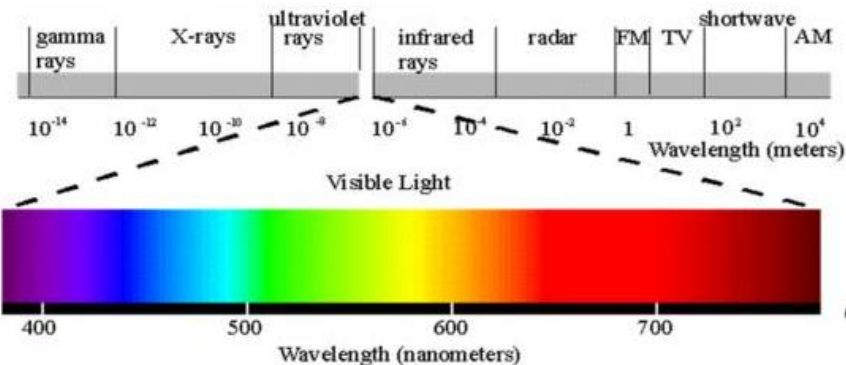
What is Light?

IESNA definition:

“Radiant energy that is capable of exciting the retina and producing a visual sensation”

3 key aspects:

- radiant energy
- excites the retina
- produces a visual sensation



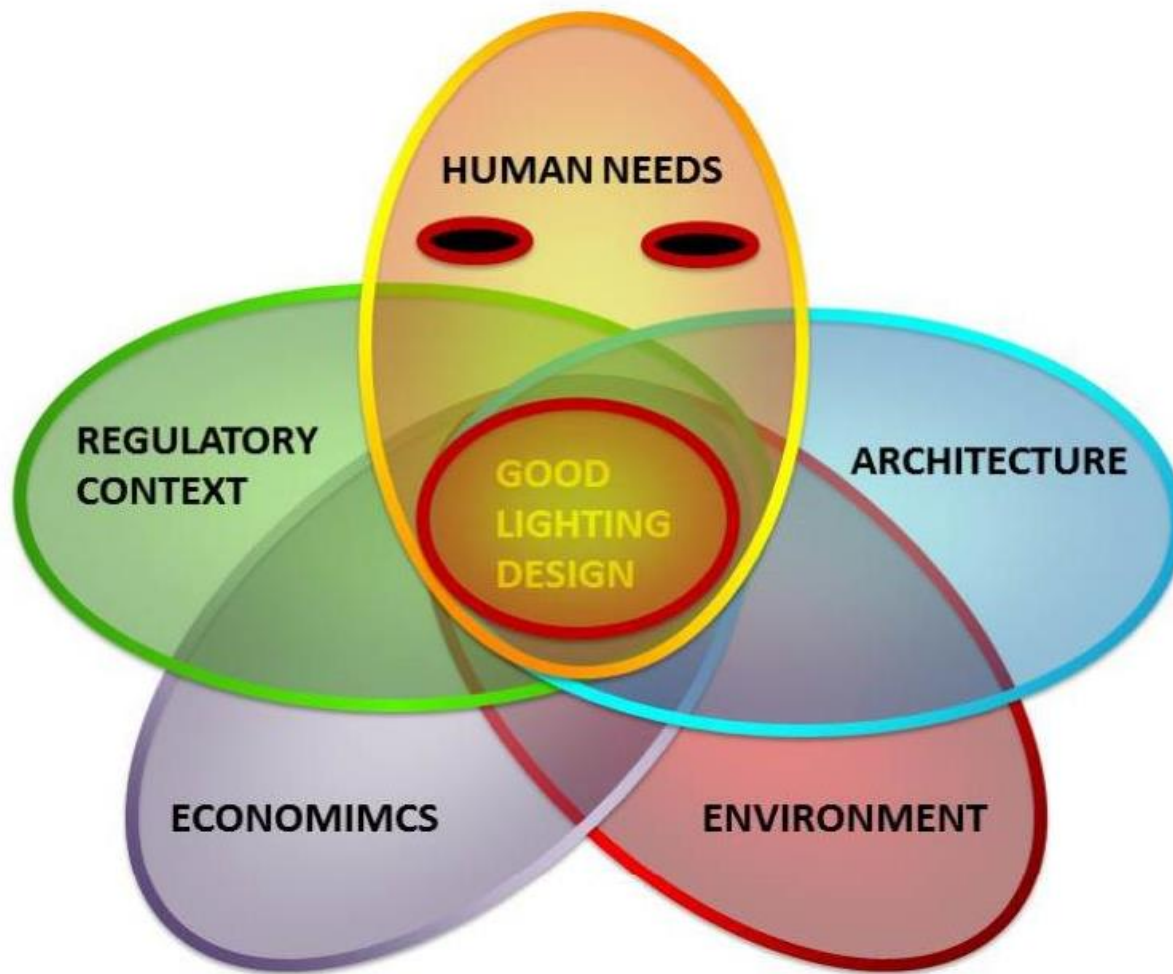
VISION

Visibility: Ability extract information from the visual filed.

**Vision
Depends on
Light**

Visual Acuity: Ability to see fine details

Good Lighting Design



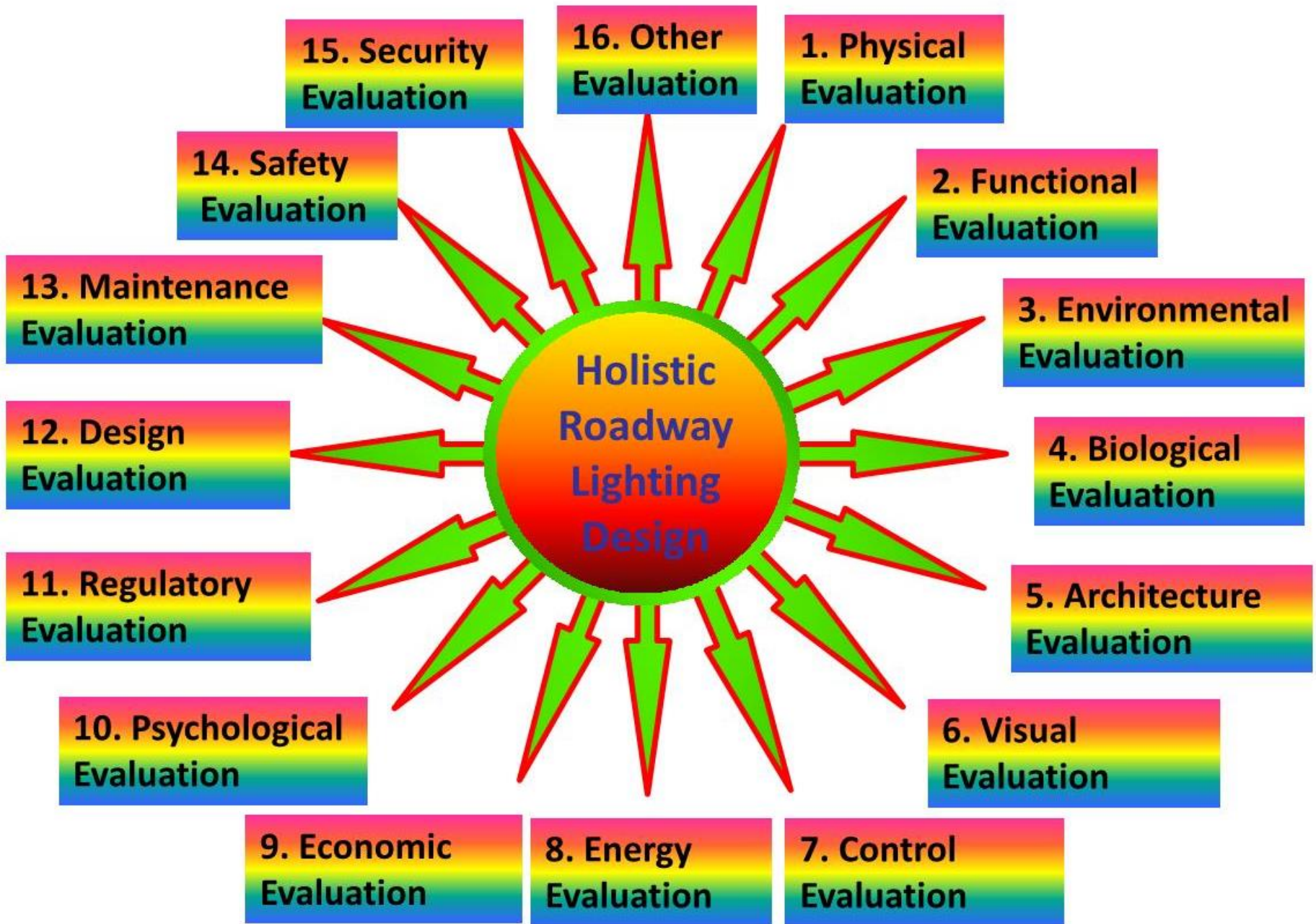
Good Lighting Design

“Good lighting design is a compromise, meeting human needs while balancing the architecture, environment, economy and regulatory context.”

Adapted from Dr. Jennifer Veitch, Ph.D.

Quality Lighting

Quality of Lighting is visual performance and visual comfort and ease of seeing



1. Physical Evaluation - Lighting Metrics Review

Luminous Flux

Lumens (lm)

Sky Glow

Luminance

Candelas per sq. meter (cd/m^2)

Candelas per sq. foot (cd/ft^2)

Candelas per sq. centimeter (cd/cm^2)

Glare

Trespass

Luminous Intensity

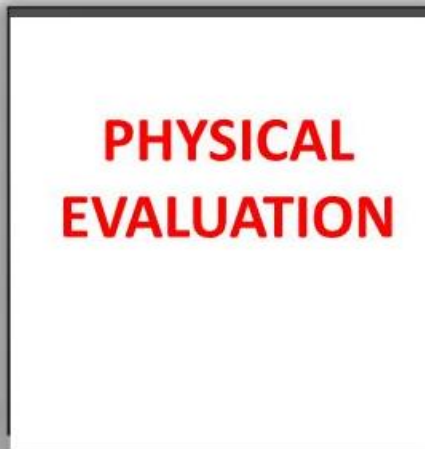
Candela (cd)

Illuminance

Foot-candle (fc, lm/ft^2)

Lux (lx, lm/m^2)

1. Physical Evaluation



Horizontal Illuminance

how much light falls on the surface of the roadway

Horizontal Luminance

how much light is reflected from the surface of the roadway

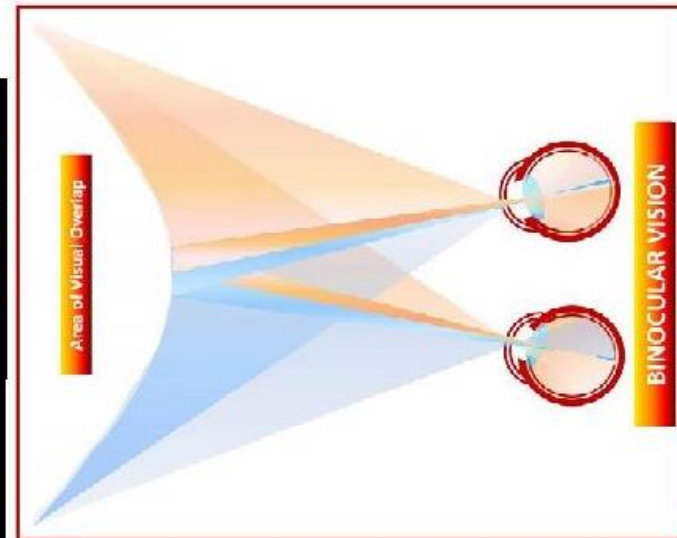
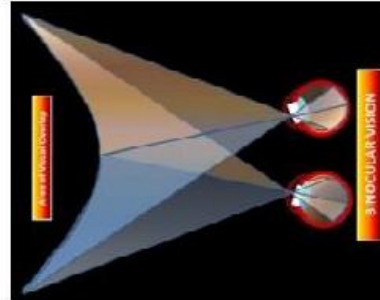
Eye Corneal Illuminance

trespass lighting measurement into the residential property

Vertical Illuminance

how much light falls on the vertical surface where pedestrian crossings are expected.

1. Physical Evaluation

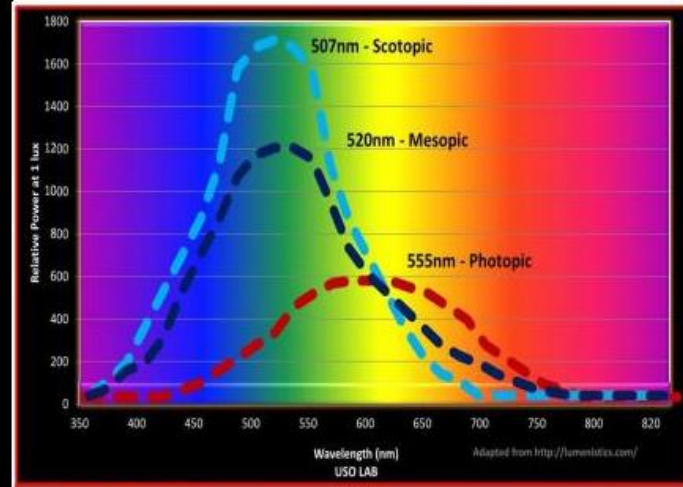


Peripheral Vision – Mesopic
(Photopic & Scotopic) lumens

Foveal Vision - Photopic
lumens



We are compromising the safety by reducing the light level using Mesopic factor (Scotopic/Photopic ratio).



--- SCOTOPIC --- MESOPIC --- PHOTOPIC

Scotopic Rods $< 0.003 \text{ CD/m}^2$	Mesopic Rods & Cones $0.003 \text{ CD/m}^2 \text{ to } 3 \text{ CD/m}^2$	Photopic Cones $> 3 \text{ CD/m}^2$
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LUMINANCE (CD/m²)

2. Functional Evaluation

❖ Classification of Roadway

Freeway, Expressway, Major, Collector, local

❖ Pedestrian Conflict

High, Low, Medium

❖ Lighting Zones

- ❖ LZ0 – No Ambient Lighting – Natural Areas
- ❖ LZ1 – Low Ambient Lighting – Rural Areas
- ❖ LZ2 – Moderate Ambient Lighting – Suburban Areas
- ❖ LZ3 – Moderately High Ambient Lighting – Urban Residential
- ❖ LZ4 – High Ambient Lighting – Urban areas with mixed residential and commercial use with high pedestrian activity

References

IESNA - RP8 - Horizontal Illuminance & Luminance

TM-11-00 & IES 10th Edition, The Lighting Handbook

3. Environmental Evaluation

❖ Light Pollution

- ❖ Trespass
- ❖ Sky Glow
- ❖ Glare

❖ Lighting Zones

- ❖ Lighting Zones LZ0 – LZ4

❖ Pedestrian Conflict

- ❖ High, Low, Medium

❖ Classification of Roadways

Reference:

IES 10th Edition, The
Lighting Handbook

❖ OTHERS

- ❖ IDA Requirement
- ❖ LEED Requirement
- ❖ ASHRAE Requirement

- ❖ Trespass / Backlight
- ❖ Sky glow / Up light
- ❖ Glare / Offensive Light

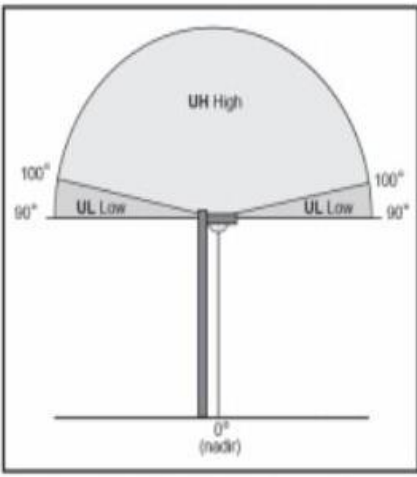
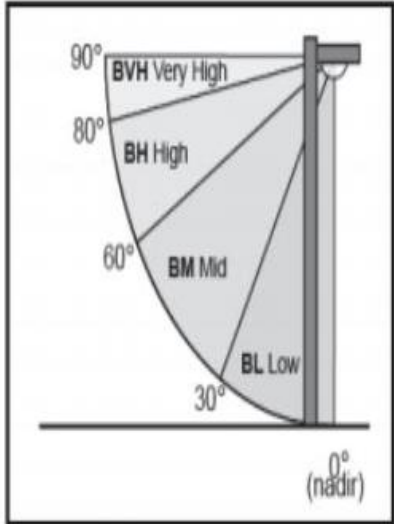


Image courtesy of LRL

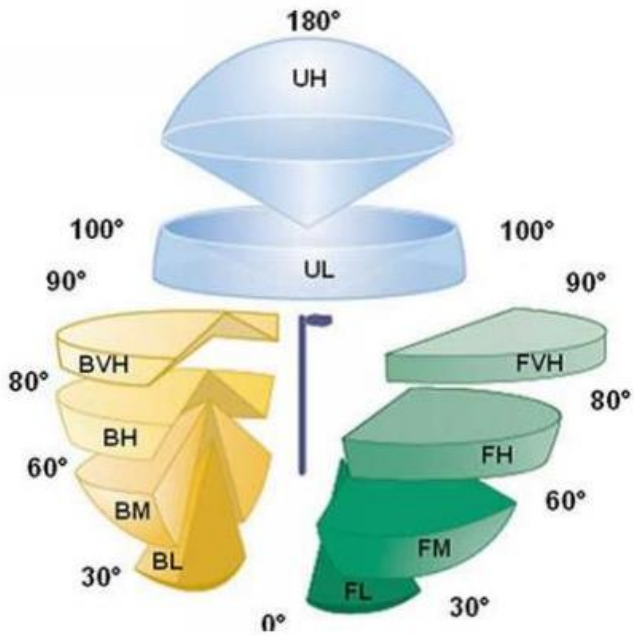
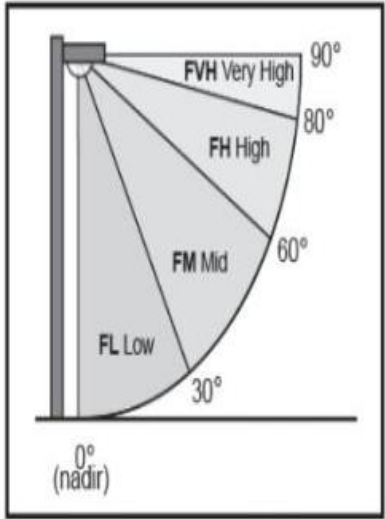
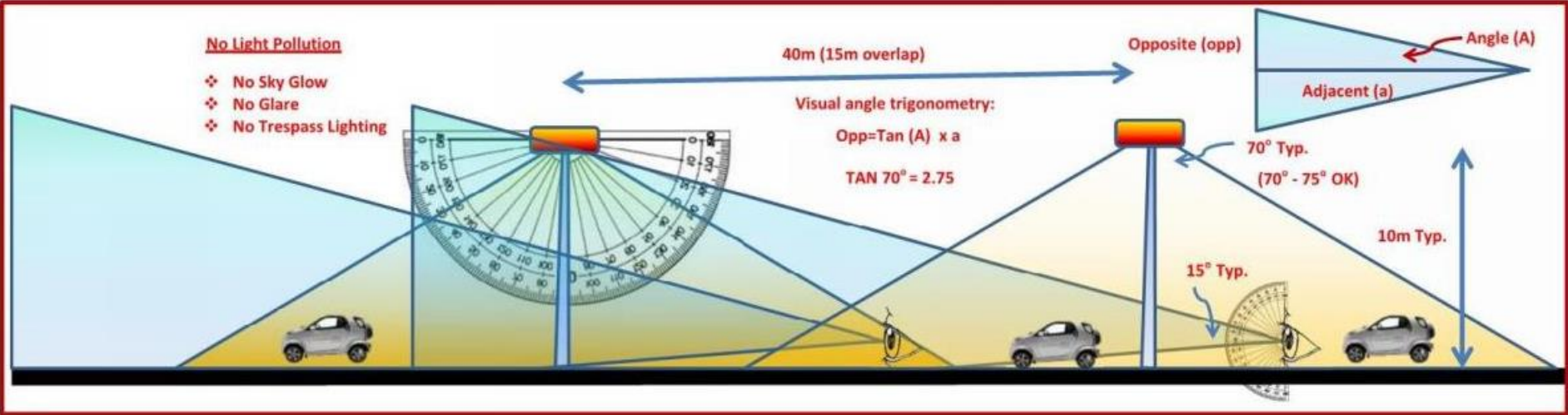


Image courtesy of LRL



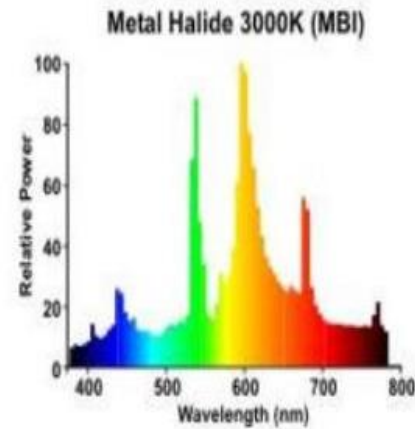
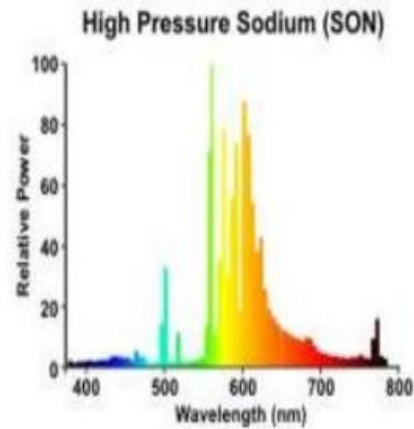
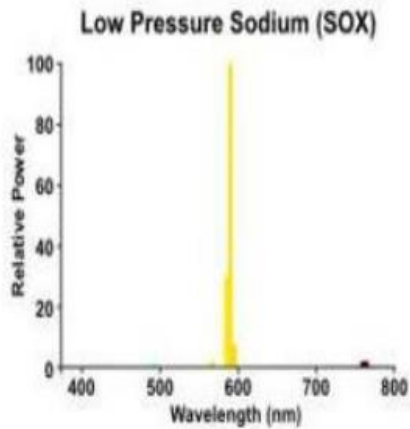
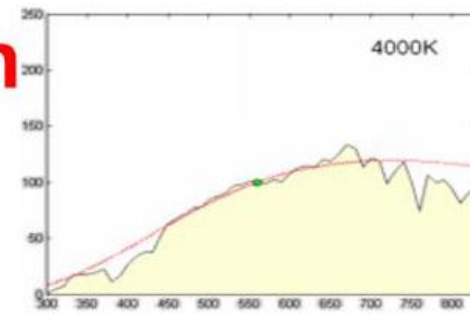
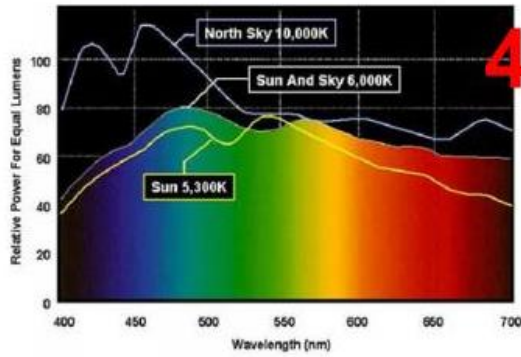
3. Environmental & Functional Evaluation

Reference: IES 10th Edition, The Lighting Handbook

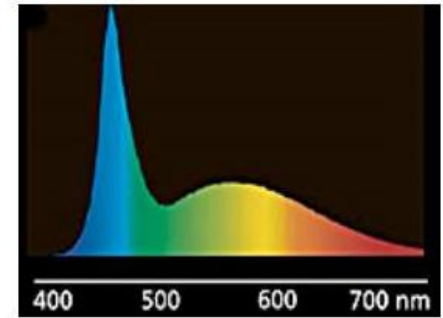
Lighting Zones	Areas – Ambient Lighting Levels	Pre-Curfew Limitation	Post-Curfew Limitation
Lighting Zones LZ0	Natural Areas- No Ambient Lighting	0.1	0
Lighting Zones LZ1	Rural Areas- Low Ambient Lighting	1	0
Lighting Zones LZ2	Suburban Areas- Moderate Ambient Lighting	3	1
Lighting Zones LZ3	Urban Residential Areas- Moderately High Ambient Lighting	8	3
Lighting Zones LZ4	*Urban Residential & Commercial Areas- High Ambient Lighting	15	6

***Urban areas with mixed use high pedestrian activity**

4. Biological Evaluation

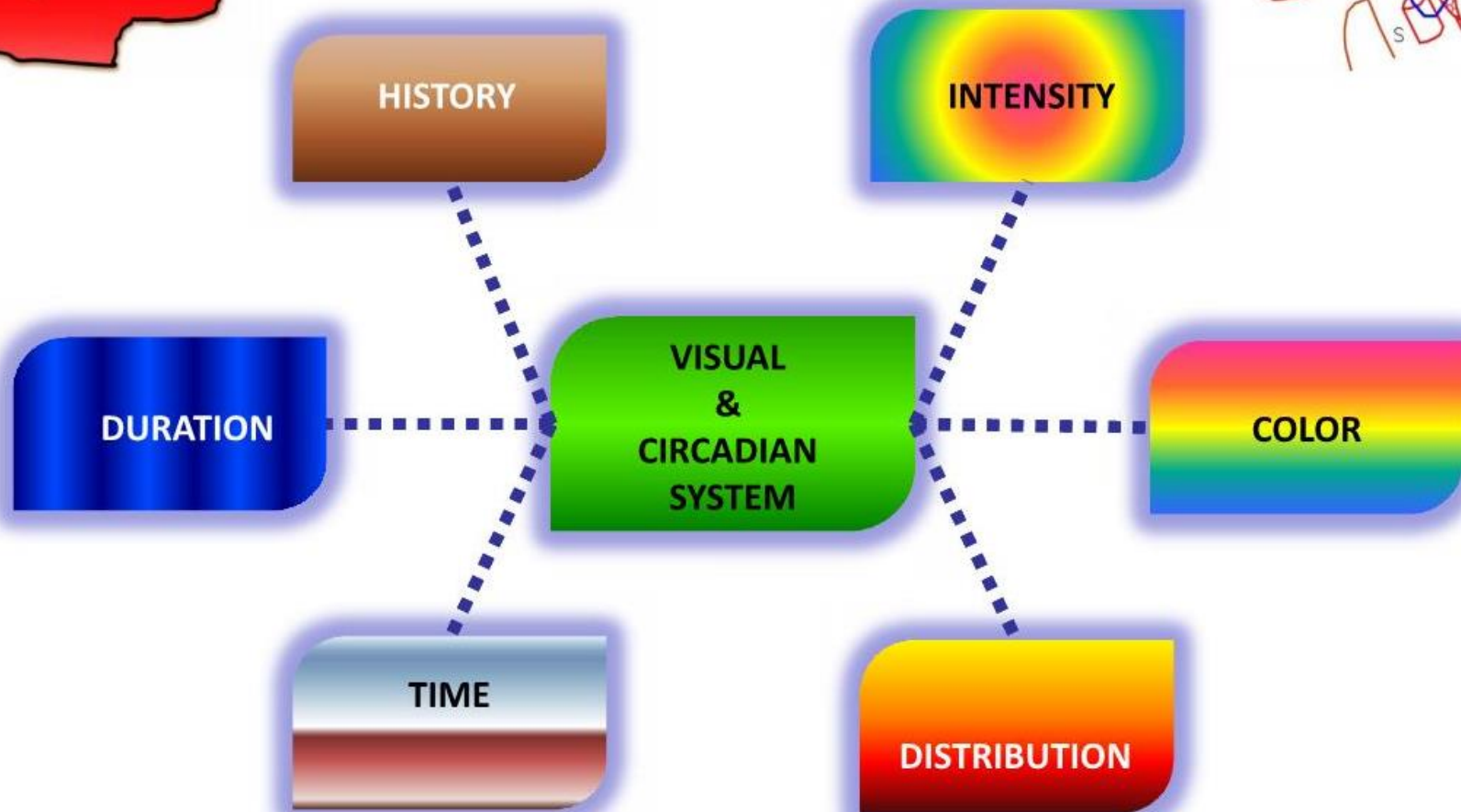
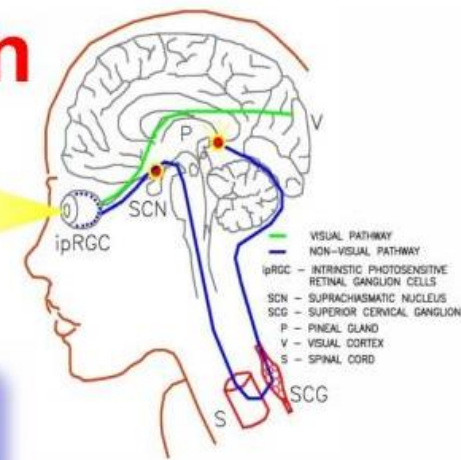
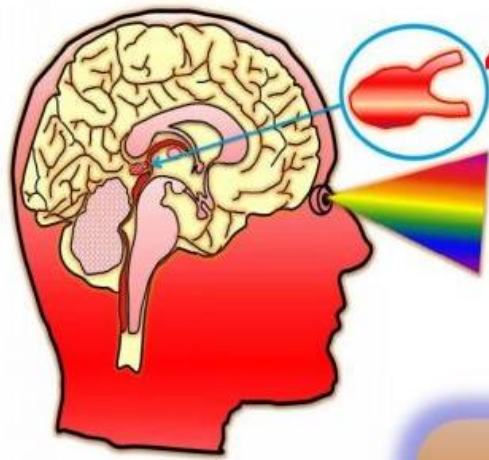


LED



4. Biological Evaluation

Visual & Circadian System



4. Biological Evaluation

Visual & Circadian System

1

In the future, It is expected that the luminaire manufacturer will provide the amount of light which causes melatonin suppression in humans.

2

A lighting designer who chooses a luminaire will know the threshold lighting level of each luminaire which suppress the melatonin.

3

As a lighting designer, we will make sure that the trespass lighting level well below the threshold level during the lighting calculation process.

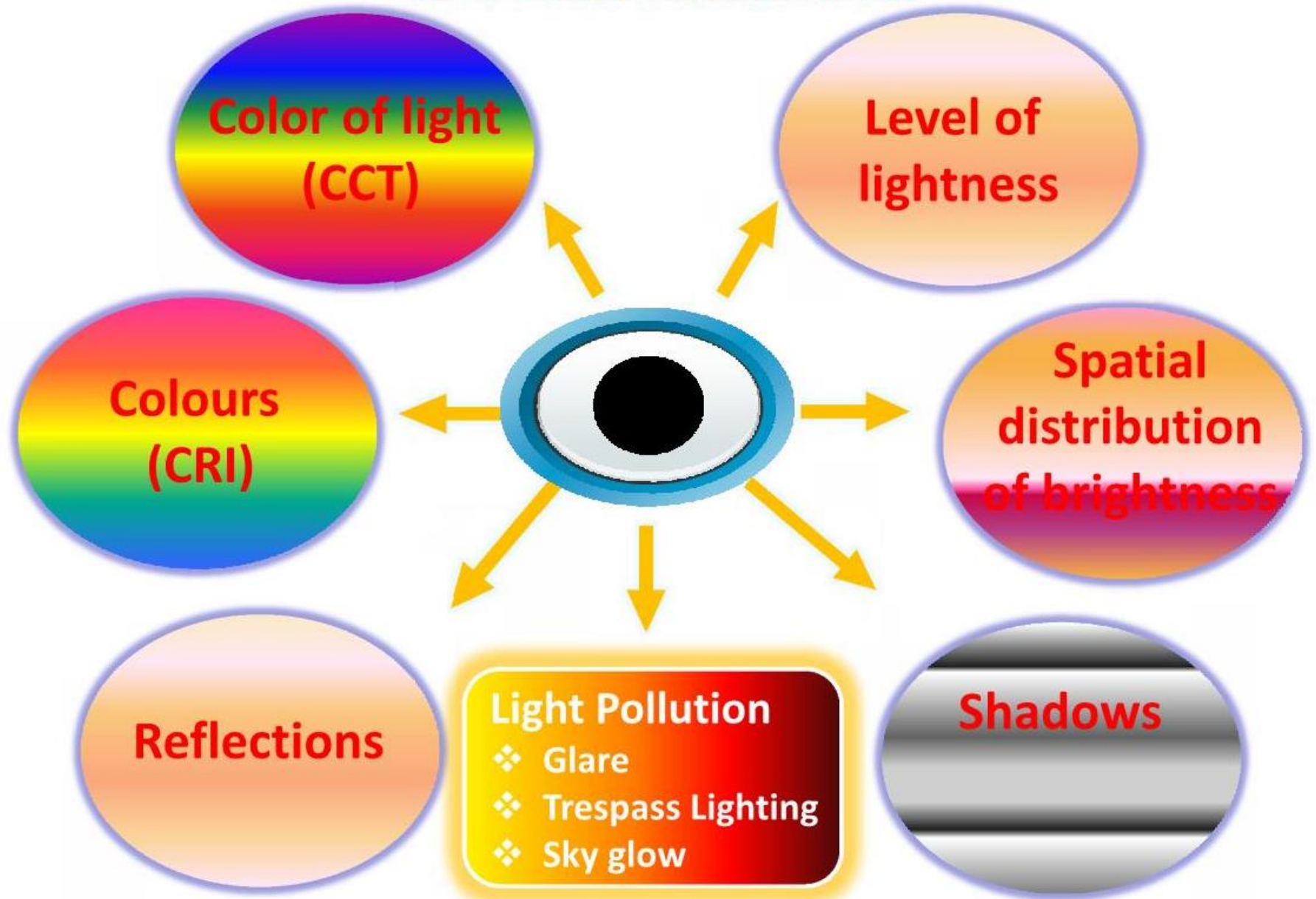
5. Architectural Evaluation



5. Architectural Evaluation



6. Visual Evaluation

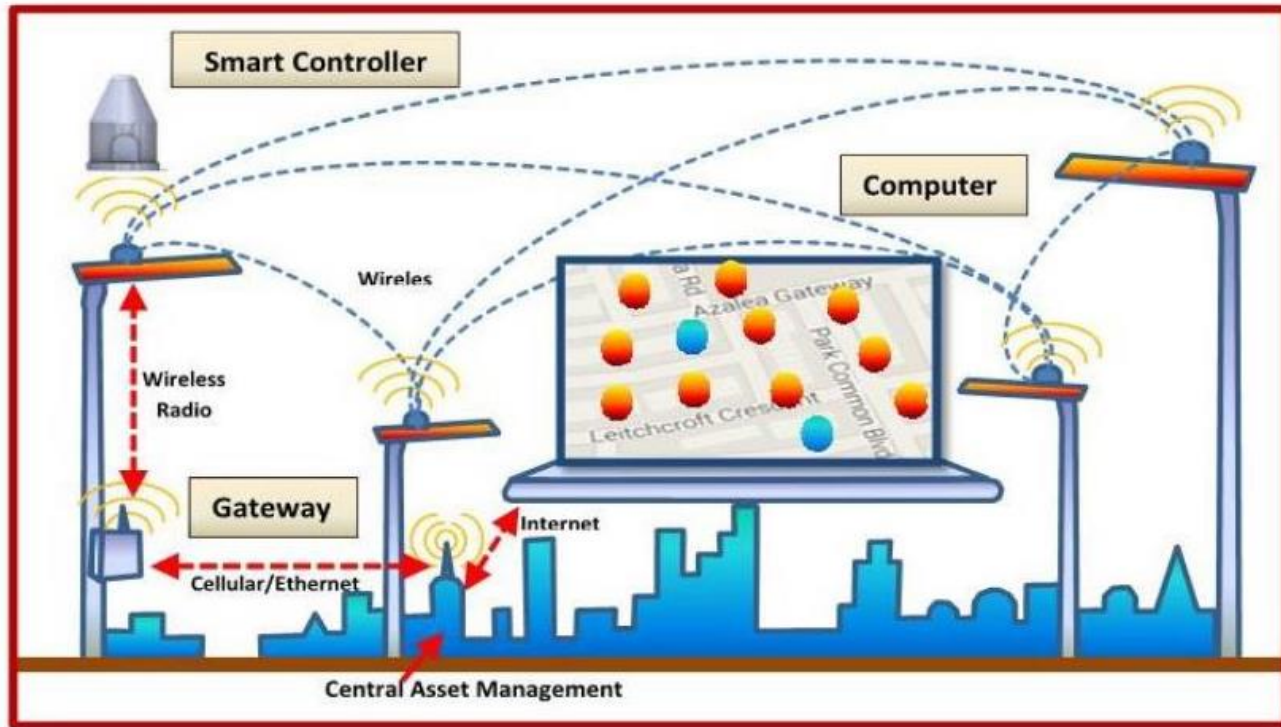


7. Lighting Control Evaluation

Lighting Control System



Sample Dimming Method



100W (0% Dim)	80W (20% Dim)	50W (50% Dim)	80W (20% Dim)
Original Light Level	Sunset – 11 PM Required Light Level	11 PM – 5 AM Non-activity Light Level	5 AM – Sunrise Required Light Level



ANSI C136.41 Dimming Receptacle

7. Lighting Control Evaluation

❖ Energy Saving

- ❖ Match Light Level to Variable Pedestrian Conflict
- ❖ Reduce Light Level to the required Levels
- ❖ Dim or turn off over-Lighted Neighbourhoods (i.e. Times Square)

❖ Light Pollution Control

- ❖ Reduce trespass
- ❖ Glare
- ❖ Sky glow

❖ Centralized Monitoring & Control

❖ Centralized Asset Management



Times Square

8. Energy Efficiency Evaluation

IESNA - RP8 - Horizontal Illuminance & Luminance

ROAD	PEDESTRIAN CONFLICT AREA	MIN. MAINTAINED AVERAGE ILLUMIN. ON PAVEMENT	UNIFORMITY RATIO	MAX. ALLOWED VEILING LUMINANCE RATIO	AVERAGE LUMINANCE	MAX. ALLOWED UNIFORMITY RATIO	MAX. ALLOWED UNIFORMITY RATIO
		R2&R3 in Lux	Eavg/Emin	Lvmax/Lavg	Lavg(cd/m2)	Lavg/Lmin	Lmax/Lmin
FREEWAY CLASS A		9.0	3.0	0.3	0.6	3.5	6.0
FREEWAY CLASS B		6.0	3.0	0.3	0.4	3.5	6.0
EXPRESSWAY	HIGH	14.0	3.0	0.3	1.0	3.0	5.0
EXPRESSWAY	MEDIUM	12.0	3.0	0.3	0.8	3.0	5.0
EXPRESSWAY	LOW	9.0	3.0	0.3	0.6	3.5	6.0
MAJOR	HIGH	17.0	3.0	0.3	1.2	3.0	5.0
MAJOR	MEDIUM	13.0	3.0	0.3	0.9	3.0	5.0
MAJOR	LOW	9.0	3.0	0.3	0.6	3.5	6.0
COLLECTOR	HIGH	12.0	4.0	0.4	0.8	3.0	5.0
COLLECTOR	MEDIUM	9.0	4.0	0.4	0.6	3.5	6.0
COLLECTOR	LOW	6.0	4.0	0.4	0.4	4.0	8.0
LOCAL	HIGH	9.0	6.0	0.4	0.6	6.0	10.0
LOCAL	MEDIUM	7.0	6.0	0.4	0.5	6.0	10.0
LOCAL	LOW	4.0	6.0	0.4	0.3	6.0	10.0

8. Energy Efficiency Evaluation

Ability to change lighting levels to suit human activity levels

❖ Energy Saving Sample Calculations

Match Light Level to Variable Pedestrian Conflict	IES RP-8 Average Light Level		Actual Percentage	Initial Energy Saving by Dimming
High	17	Lux	100%	0%
Medium	13	Lux	76%	24%
Low	9	Lux	53%	47%

Reduce Light Level to the required Levels				
Average Light Level is Required	17	Lux	100%	0%
Average Design Light Level with 70% LLF	20	Lux	118%	18%
Average Initial Lighting on the Field	28.57	Lux	168%	68%

Dim-or turn off over-Lighted Neighbourhoods				
Based on demand and/or requirement	0-17	Lux	100%	0%-100%

9. Economic (& Energy) Evaluation

Lamp Type	Lamp Wattage (watts)	Line Wattage (watts)	Lamp Life (hrs)	Lamp Life (years) (11.5X365) [maintenance cycle]	Fixture Cost	Maintenance Cost (per year)	Maintenance Cost (normalized to the LED fixture life)	Energy Cost (per year)	Energy Cost (normalized to the LED fixture life)	Total Cost of the Fixture (normalized to the LED fixture life)
100 W MH	100	122	12000	2.9	\$175.00	\$87.45	\$1,458.33	\$51.21	\$854.00	\$2,487.33
100 W HPS	100	128	24000	5.7	\$150.00	\$43.72	\$729.17	\$53.73	\$896.00	\$1,775.17
70 W LED	70	70	70000	16.7	\$617.00	\$14.99	\$250.00	\$29.38	\$490.00	\$1,357.00

Luminaire Usage	11.5 hrs/night	LED Energy Savings in Comparison to:	
	4197.5 Hrs/year		
		100 W MH	42.62%
		100 W HPS	45.31%
Maintenance Cost	\$250.00	Return on Investment for LED Fixture:	
Electricity Cost	\$0.10 per kW/hr	100 W MH	3.2 years
		100 W HPS	4.8 years

* The above comparison shows typical lamp data for a 100 Watt MH lamp, a 100 Watt HPS lamp and an 70 Watt LED light source.

* The LED fixture has a higher initial cost, however the savings come from the savings in maintenance and the savings in energy costs.

* The LED fixture starts saving money over the metal halide fixture after 3.2 years.

* The LED fixture starts saving money over the high pressure sodium fixture after 4.8 years.

9. Economic Evaluation

❖ Energy Saving

- ❖ Energy Efficient Light Sources reduce electricity expenses.
- ❖ Dim or turn off over-Lighted Neighbourhoods.

❖ Operation and Maintenance Savings

- ❖ Long life span Light Sources reduce re-lamping costs.
- ❖ Operation and maintenance costs.
- ❖ Replacement cost of shorter life light sources.
- ❖ Salvaged and/or disposal costs if any.

❖ Benefit Cost Analysis

- ❖ Current Benefit Cost Analysis based on the Accident Data and the corresponding dollar value. **We do not have the dollar value for the environmental benefits.**

10. Psychological Evaluation

(Test Site or Mock-up location)

SURVEY – Survey people to find out that the lighting installation meets the human needs while balancing the architecture, environment including cognition, safety and comfort.

QUESTIONS	1	2	3	4	5	6	7	8	9	10
1. How would you describe the current lighting ? a) Comfortable b) Uncomfortable (Glare) c) Distracting (visually confusing)										
2. Should the visibility of the light be improved? a) Yes b) No										
3. Can you be able to see the pedestrian while crossing? a) Yes b) No										
4. Can you be able to read the signs during the Night? a) Yes b) No										

11. Regulatory Evaluation



❖ IESNSA



Illuminating
ENGINEERING SOCIETY

- ❖ IESNA The Lighting Handbook, 10th Edition
- ❖ IESNA's RPs, DGs, Gs, TMs, LM, etc.

❖ IDA

- ❖ International Dark Sky Association Requirement.

❖ LEED

- ❖ Leadership in Energy and Environmental Design Requirement.

❖ Local Government

❖ Others – Electrical, Structural & Building Code.

12 & 13. Design & Maintenance Evaluation

❖ Design Evaluation

❖ Workable Design & Functional Installation

❖ Operation and Maintenance Evaluation

❖ Required space for maintenance

❖ Required skill for maintenance of new technology

14 &15. Safety & Security Evaluation

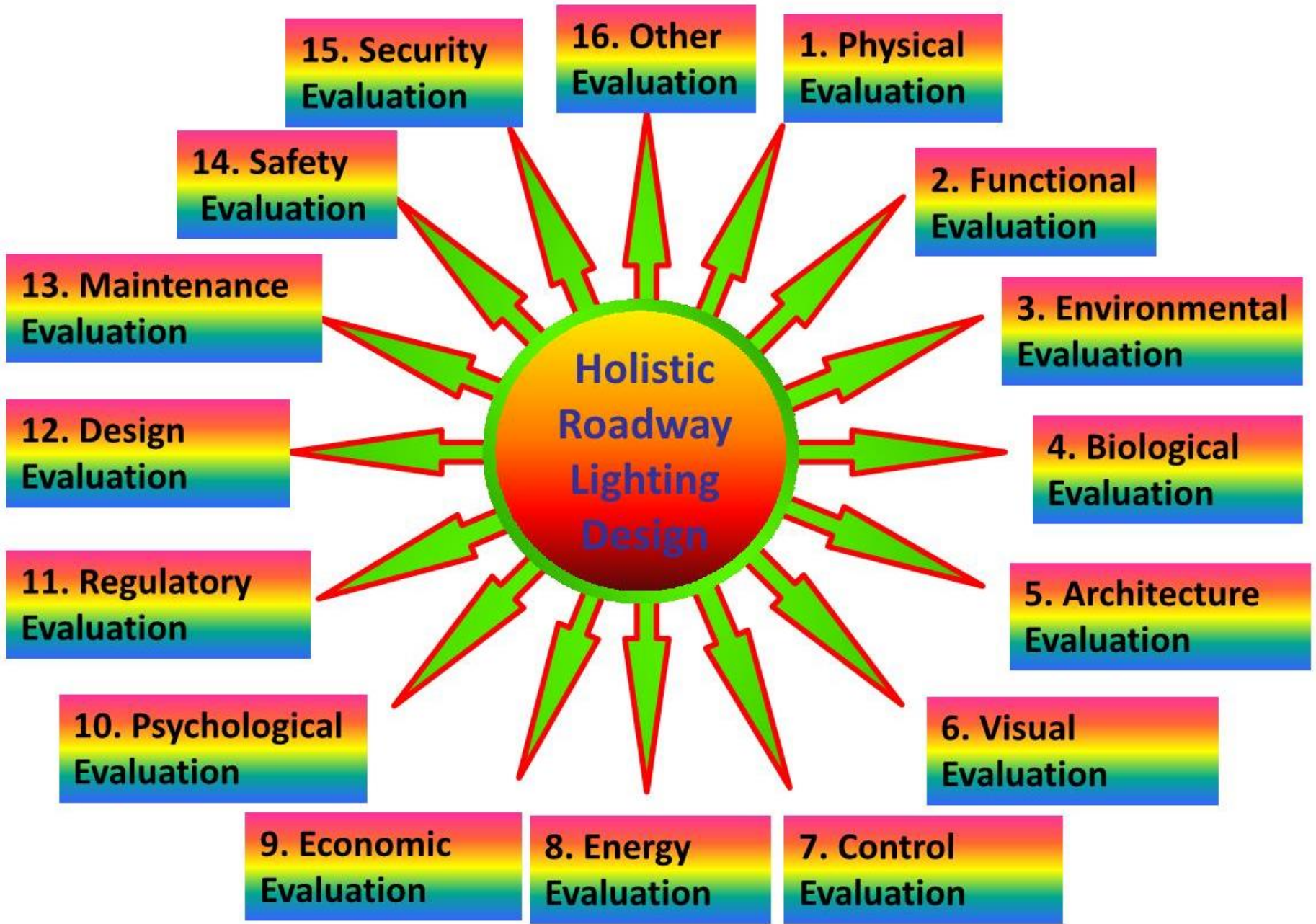
❖ Security Evaluation

- ❖ Required light levels in the right places (lux/fc)
- ❖ Uniform lighting design (Max/Min, Ave./Min.)
- ❖ Light Pollution Control (BUG ratio)
- ❖ No Glare - No “blinding light.”
- ❖ Good luminance & color contrast.
- ❖ Good Vertical Illuminance for CCTV if required
- ❖ Good Transition lighting, etc.

14 & 15. Safety & Security Evaluation

❖ Safety Evaluation

- ❖ Location of pole & type (pole setback)
- ❖ Constructability (overhead and under ground hydro lines and other utilities)
- ❖ Wind loading (EPA)
- ❖ Structural Stability of pole & footing.
- ❖ Electrical safety of the installation (Grounding, etc.)
- ❖ Operation and Maintenance Safety (hydro lines, etc.)



Thank you for your attention!

Have a blessed wonderful day!

Any Question?

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