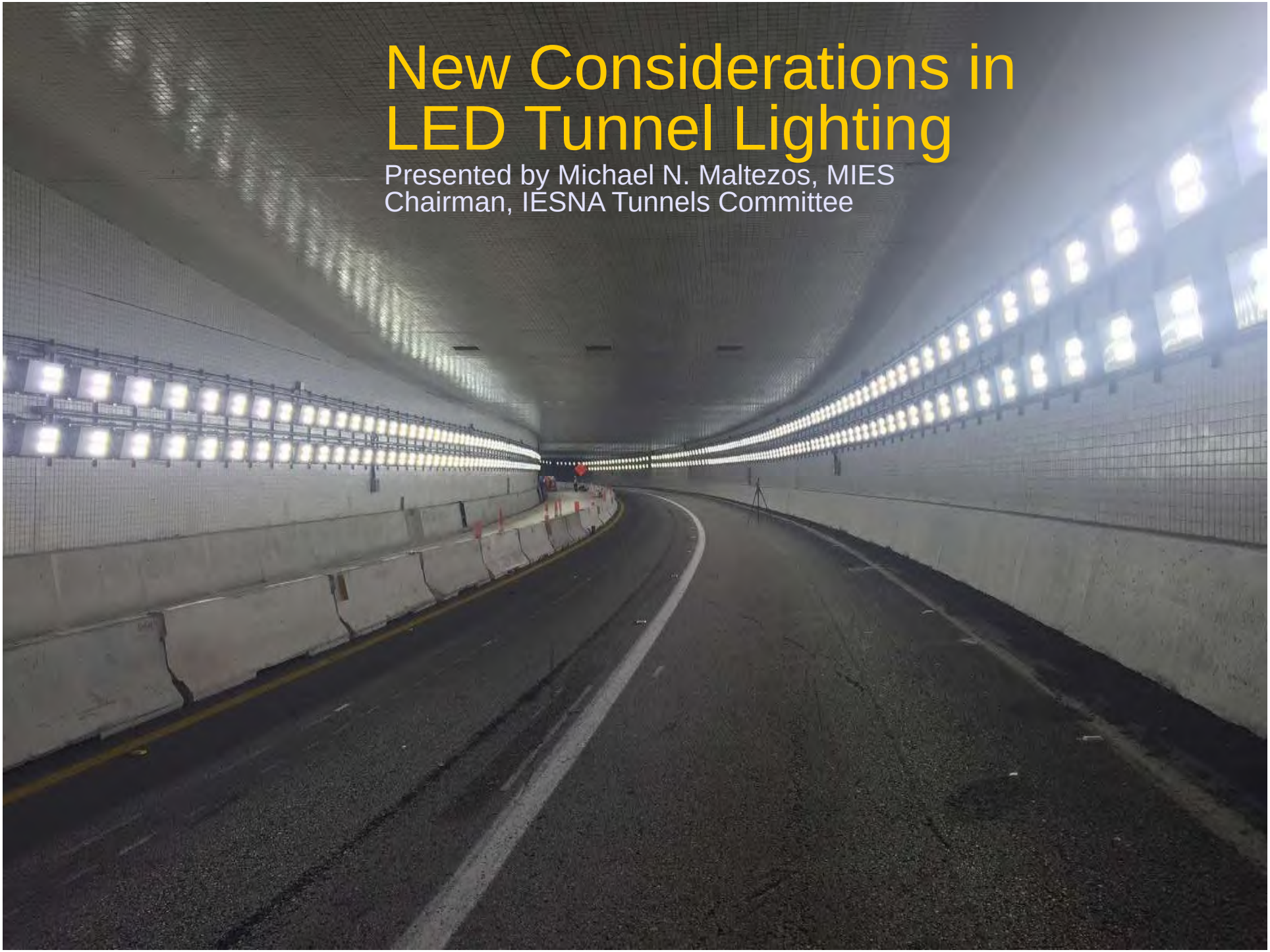


New Considerations in LED Tunnel Lighting

Presented by Michael N. Maltezos, MIES
Chairman, IESNA Tunnels Committee

Michael N. Maltezos, MIES

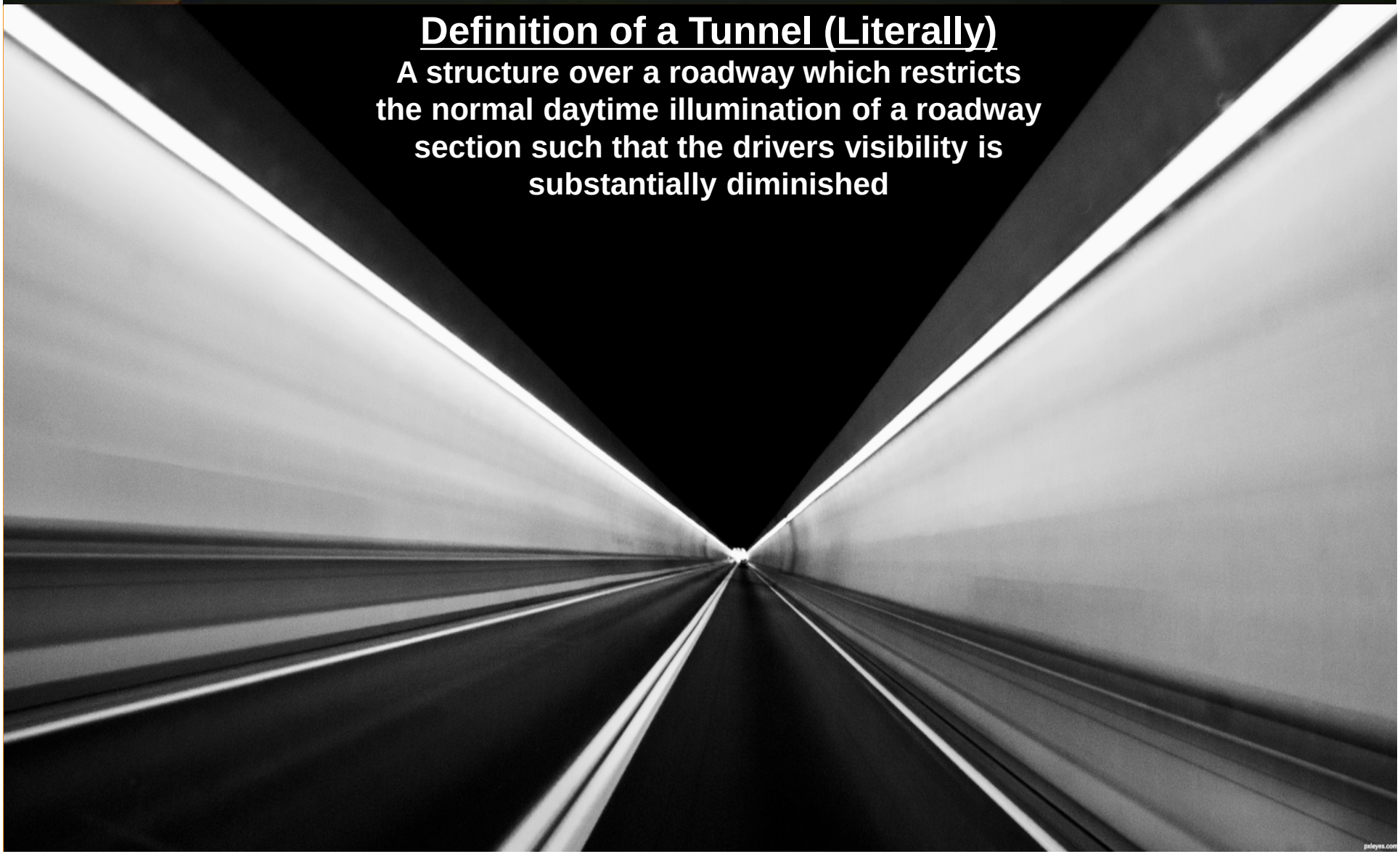
Bonjour!!!!

Michael is the International Transportation Sales Manager for Kenall Manufacturing Co. Michael possesses over 25 years' experience in the field of roadway, tunnel and transit lighting. In particular, Michael is considered a subject matter expert in the very specific application of roadway and transit tunnel lighting. Michael is currently Chairman of the IESNA Tunnels/Underpasses Committee, which is responsible for the ANSI/IESNA RP-22 Recommended Practice for Tunnel Lighting.

Before joining Kenall, Michael was the Tunnel and Transit Specialist for Schreder Lighting. Prior to Schreder, he was the President of Maltezos & Associates, performing Transportation lighting design and related consulting services. Michael was previously employed by CTE Engineers as a Senior Associate, working with DOTs around the country in implementing their project/program management and design.

Michael earned several lighting design awards from 1999-2008 through the International Illumination Design Awards (IIDA) and Illuminating Engineering Society of North America (IESNA). He is a Member of the IESNA Street & Area Lighting Committee and the IESNA Roadway Lighting Committee, and is also a Member of the CIE's Liaison Committee with the IESNA.

A COMPLEX SUBJECT



Definition of a Tunnel (Literally)

A structure over a roadway which restricts the normal daytime illumination of a roadway section such that the drivers visibility is substantially diminished

LEARNING OBJECTIVES

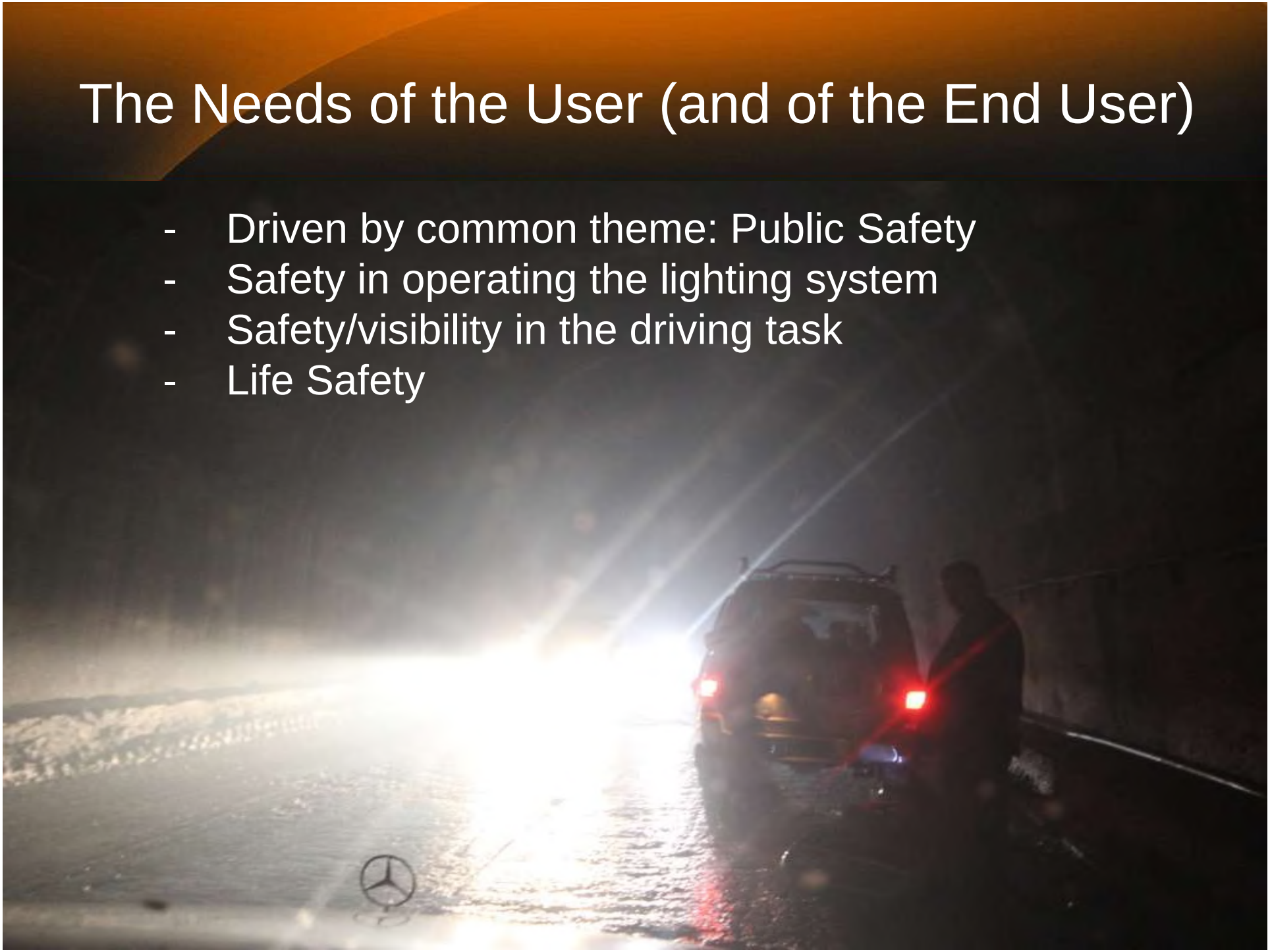
Attendees of this presentation will learn:

- The Needs of the User (and of the End User)
- Problems & Challenges with Tunnel Topology
- Lighting Application Techniques
- LED Lighting Design Considerations
- LED Lighting System Economics
- LED Maintenance Considerations
- The True “Definition” of a Tunnel
- LED Luminaires
- Controls with LED Luminaires

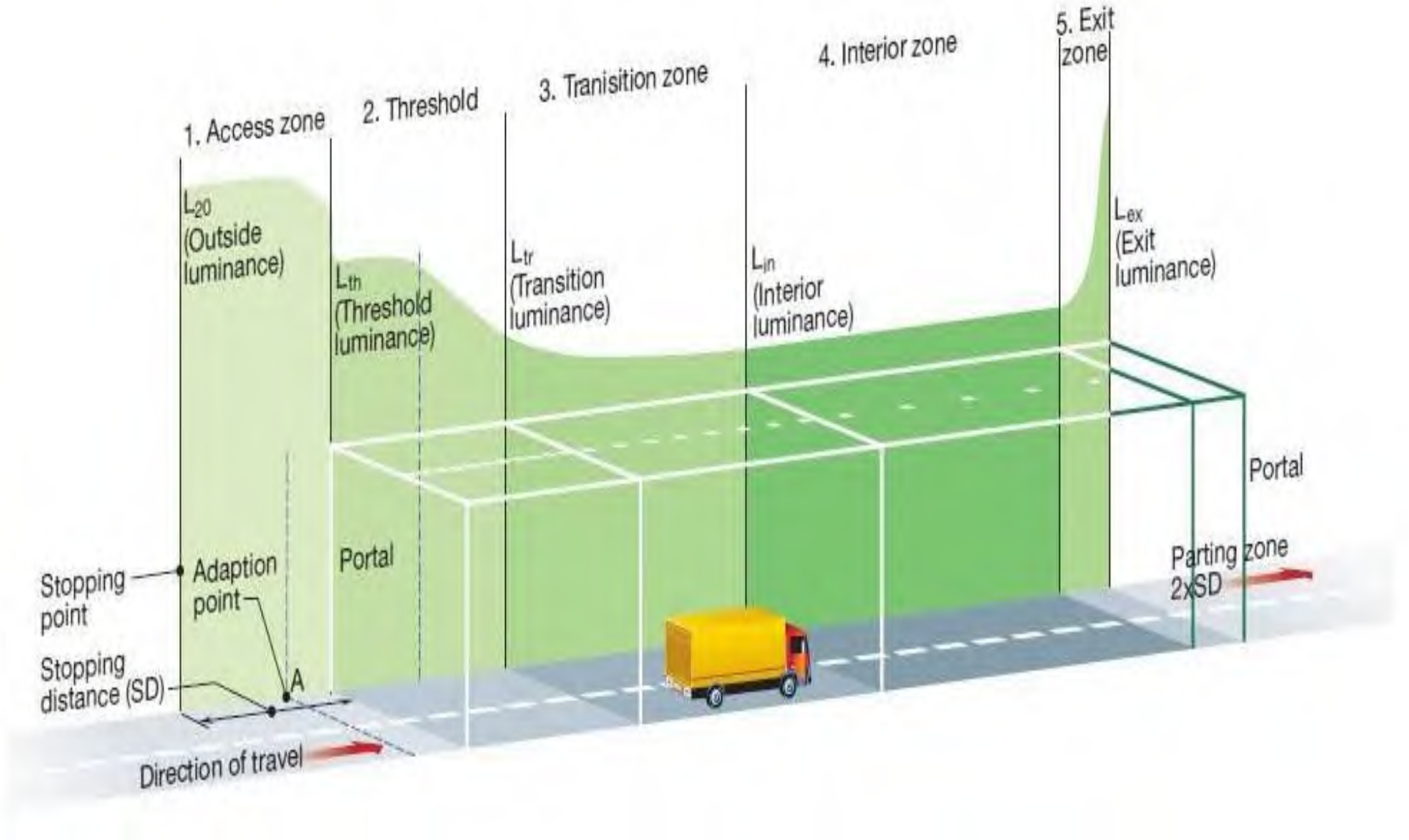
This Presentation is Also Designed to Help You Write Effective Specifications Based on the Industry's Best Practices for LED Tunnel Lighting

The Needs of the User (and of the End User)

- Driven by common theme: Public Safety
- Safety in operating the lighting system
- Safety/visibility in the driving task
- Life Safety



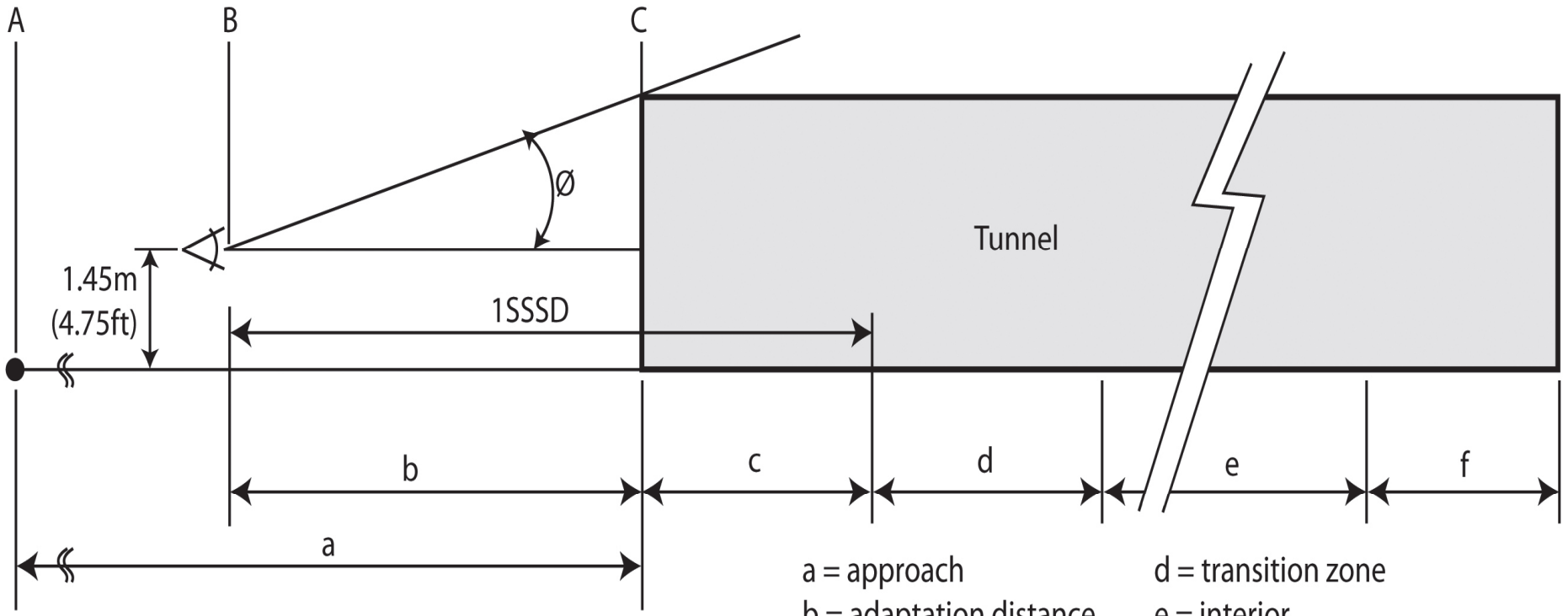
Problems & Challenges with Tunnel Topology – The Tunnel Zones



It All Starts with…Tunnel Topology…

A = Fixation Point
B = Adaptation Point
C = Portal
Ø = 22 to 25°

…per CIE-88 or ANSI/IESNA RP-22.



a = approach
b = adaptation distance
c = threshold zone
d = transition zone
e = interior
f = exit zone

Problems & Challenges with Tunnel Topology

Access Zone L20

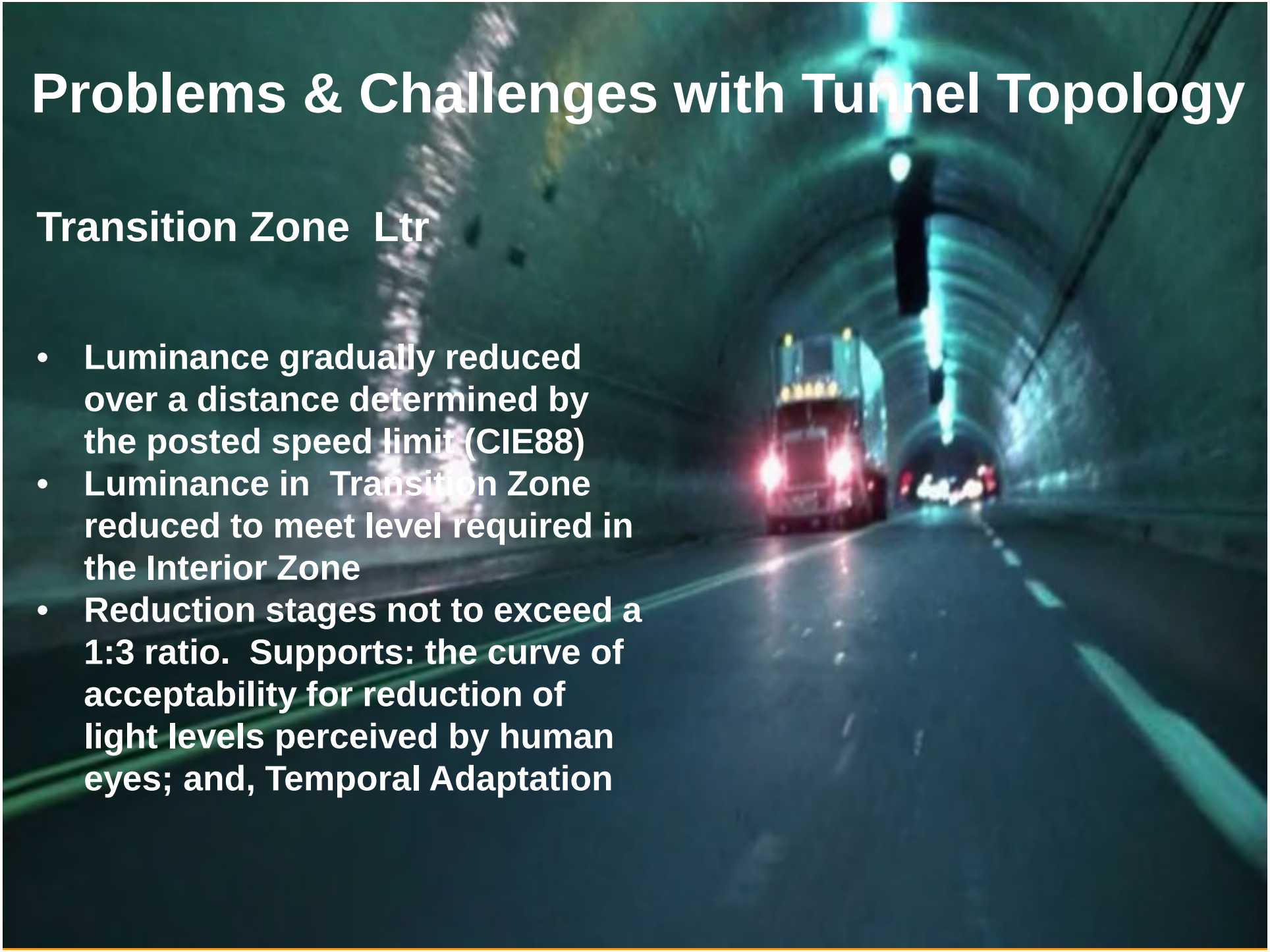
- Light Contrast
- “Black Hole”
- Adaptation

Problems & Challenges with Tunnel Topology

Threshold Zone Lth

- **Spatial Adaptation: Driver goes from wide field of vision outside tunnel…to narrow field of vision entering tunnel**
- **Temporal Visual Adaptation: Upon entering tunnel, driver suddenly goes from high luminance levels (i.e., daylight) outside to low a very luminance level inside the tunnel**

Problems & Challenges with Tunnel Topology

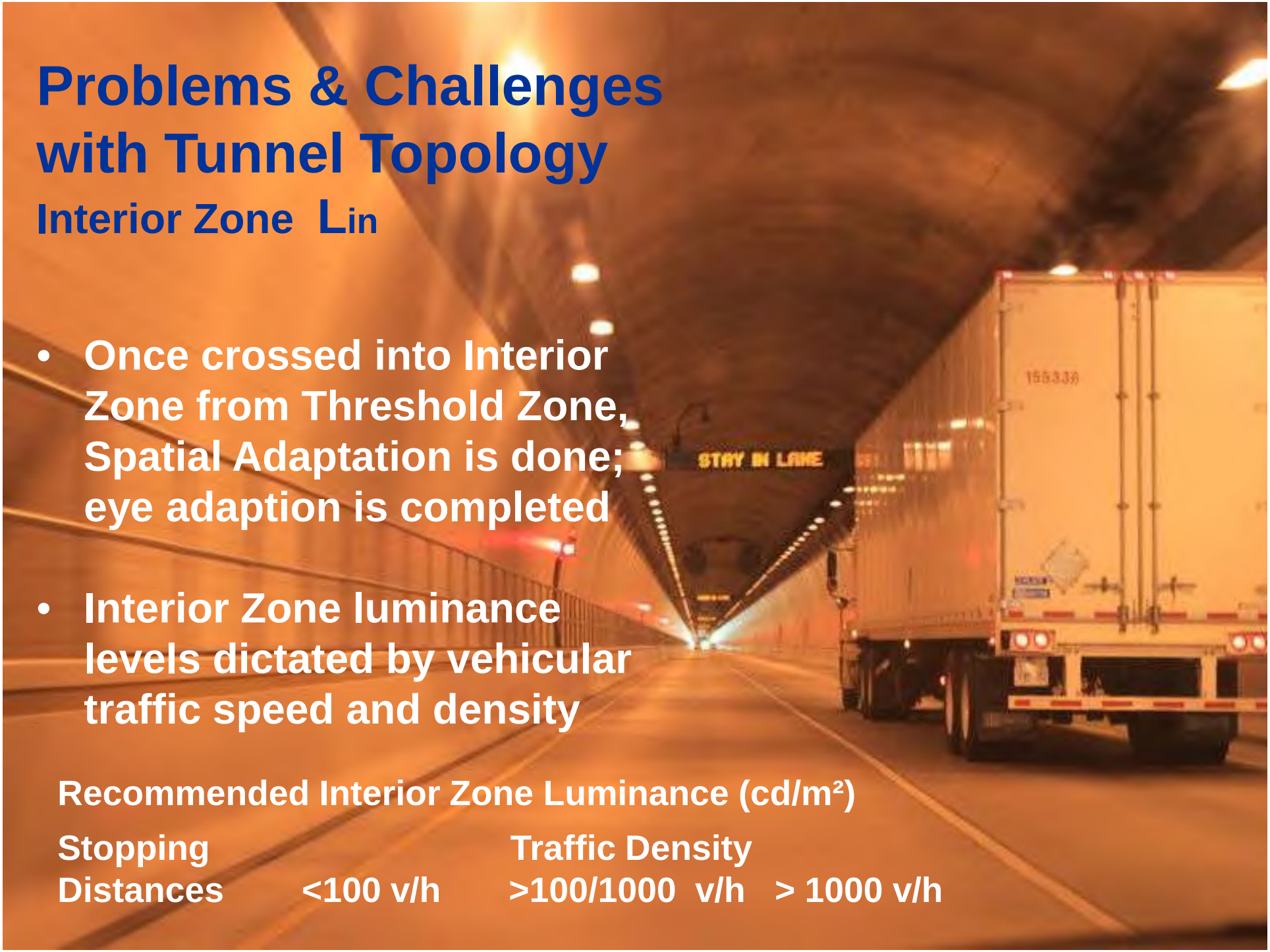


Transition Zone Ltr

- Luminance gradually reduced over a distance determined by the posted speed limit (CIE88)
- Luminance in Transition Zone reduced to meet level required in the Interior Zone
- Reduction stages not to exceed a 1:3 ratio. Supports: the curve of acceptability for reduction of light levels perceived by human eyes; and, Temporal Adaptation

Problems & Challenges with Tunnel Topology

Interior Zone L_{in}



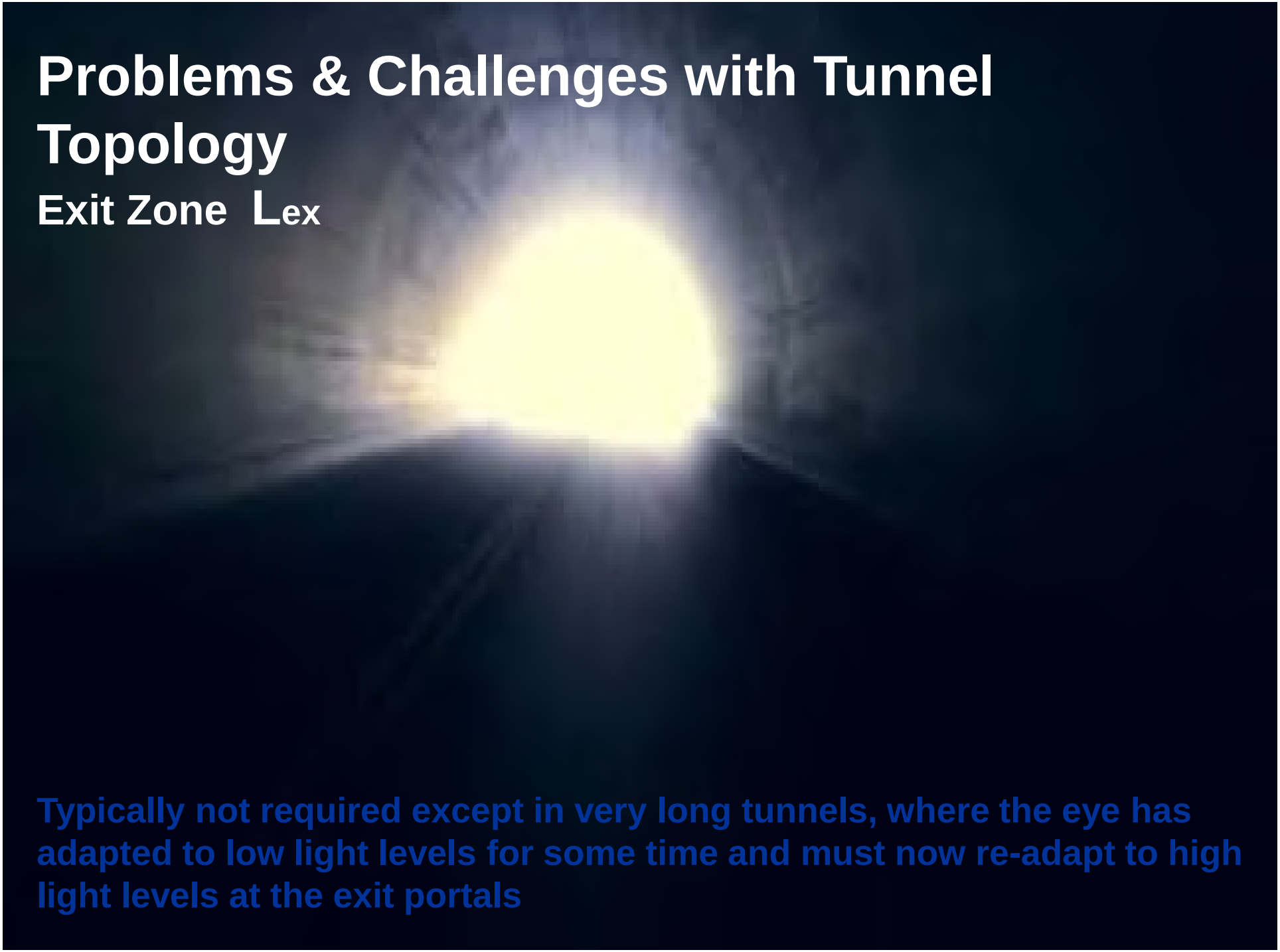
- Once crossed into Interior Zone from Threshold Zone, Spatial Adaptation is done; eye adaption is completed
- Interior Zone luminance levels dictated by vehicular traffic speed and density

Recommended Interior Zone Luminance (cd/m²)

Stopping Distances	Traffic Density <100 v/h	>100/1000 v/h	> 1000 v/h

Problems & Challenges with Tunnel Topology

Exit Zone L_{ex}



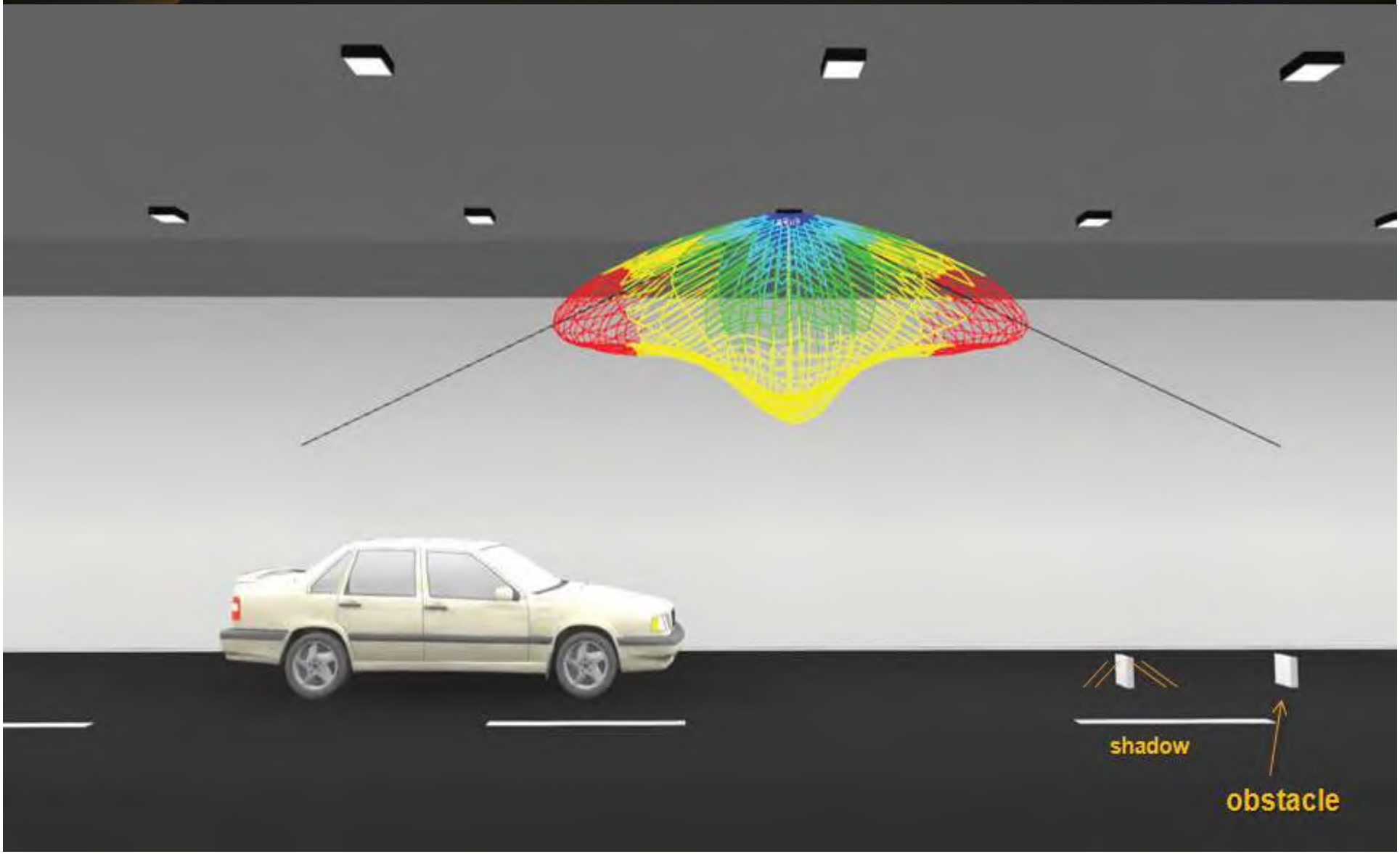
Typically not required except in very long tunnels, where the eye has adapted to low light levels for some time and must now re-adapt to high light levels at the exit portals

Problems & Challenges

Other Considerations in the brave new world of LEDs

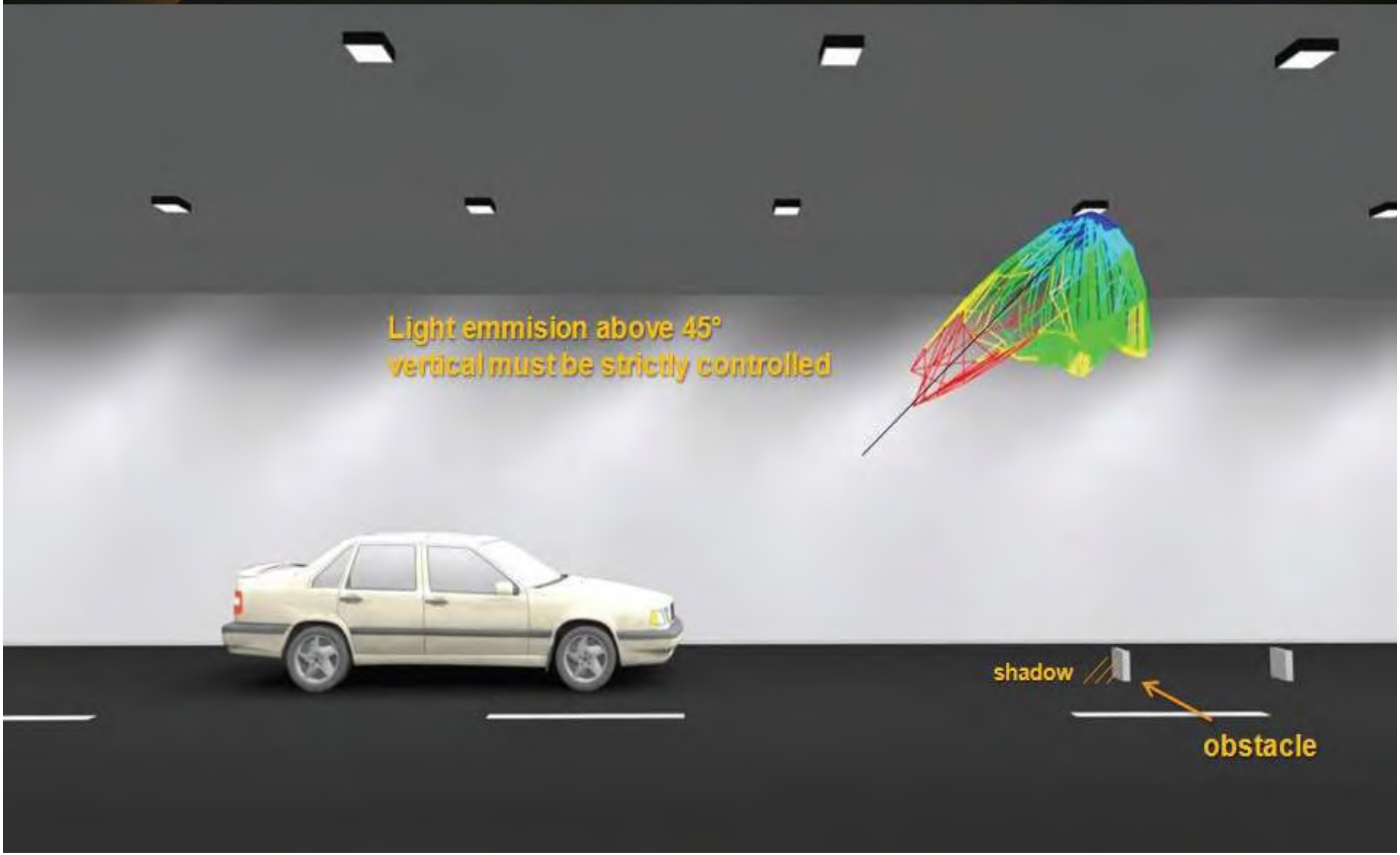
Lighting Application Techniques

Symmetrical Distribution

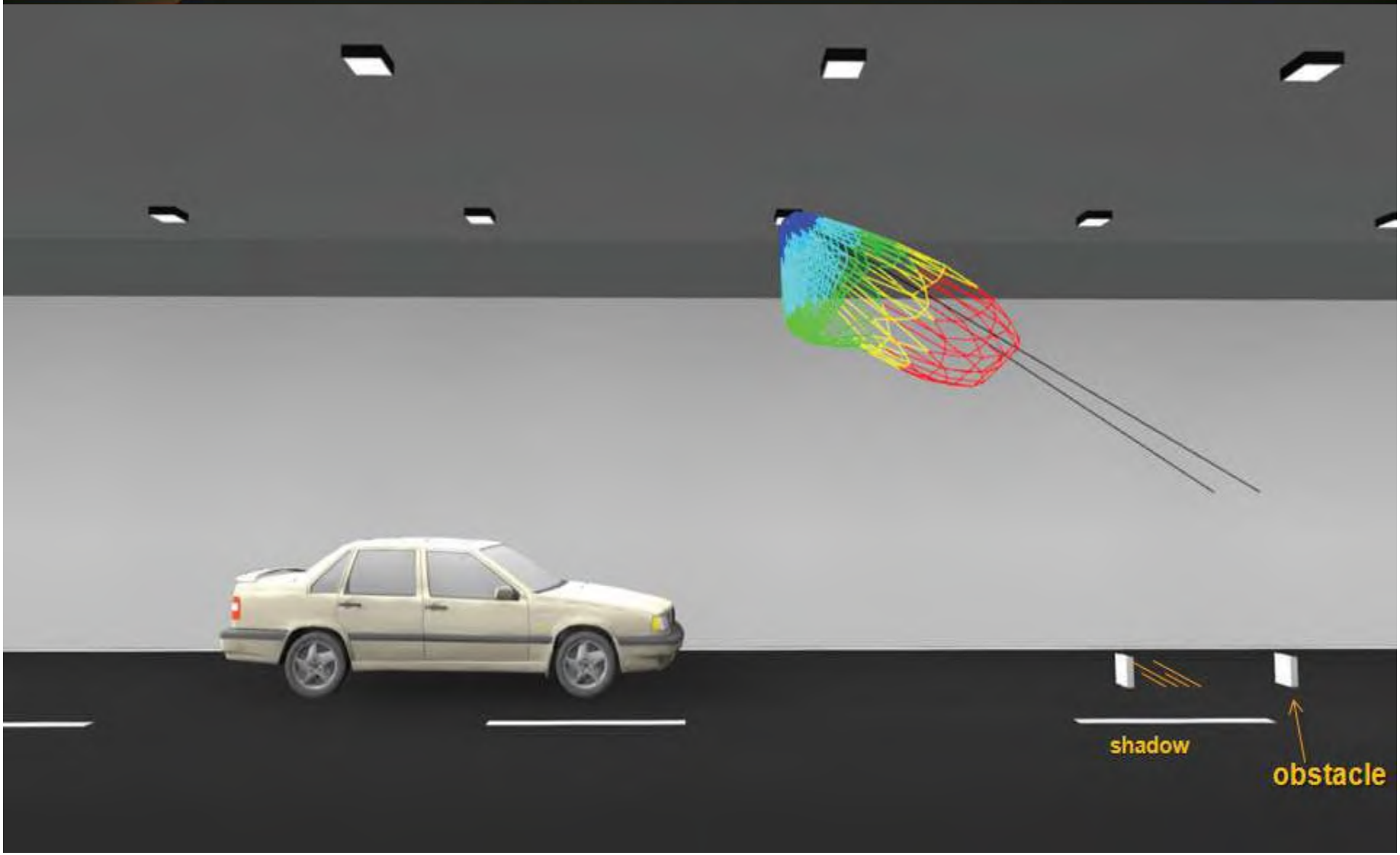


Lighting Application Techniques

Asymmetrical Distribution (Negative Contrast)



Lighting Application Techniques
Asymmetrical Distribution (Positive Contrast)



Lighting Design Considerations

Lighting Design Considerations – Tunnel Geometry, Architectural Features, & Materials

- Tunnel lighting systems are expensive to install and operate; as such, minimizing luminance of Exterior Portal surfaces and increasing luminance of interior tunnel surfaces will reduce $$

- Tunnel Pavement: Reflectance AND Luminance Contrast must be taken into accord; some pavement surfaces will have higher reflectance, but may NOT enhance contrast because of diffuse reflectance characteristics (e.g., Portland Cement Concrete)

- Tunnel Architectural Features: Different tunnel cross-sections and shapes will influence luminaire placement and light inter-reflection; e.g., “horseshoe”-shape tunnels tend to absorb light

Lighting Design Considerations

Lighting Design Considerations – Tunnel Lighting Sources (OK, “Source”; it’s all LEDs…)

- Tunnel lighting systems are expensive to install and to operate; take note of ALL considerations shown in IES RP-22 Section 9.1

- LEDs: Interesting to note….ALL jobs we are currently involved with, in design, will go LED. Further interesting note…SSL is the ONLY light source technology currently funded by the U.S. DOE

- LEDs: Based on recent efficacies...Threshold Zone was ALWAYS the problem, and relegated cost payback analyses to a proverbial circular file! However, LED chip efficacies are ever-improving…so…tunnel lighting cost payback analyses are as well

- LEDs: Drive Current in the Threshold/Transition Zones? Hmm..

Maintenance Factor (LLF) Considerations

Reflects old light source technologies; how valid is this now, for LEDs??

Table 9: Typical Values for Maintenance Consideration Factors	
Maintenance Considerations Above	**Range of Possible Values**
Lamp Lumen Maintenance	0.50 to 0.95
Lamp Burnouts	0.30 to 0.99
Luminaire Dirt Depreciation (LDD)	0.10 to 0.95
Equipment Factors (EF)	0.50 to 0.95
Ambient Temperature	0.20 to 0.99
Voltage	0.87 to 1.13
Ballast & Lamp Factor	0.85 to 0.90
Tunnel Surface Reflectance	0.20 to 0.90
Luminaire Cleaning	0.10 to 0.90
Total Typical Maintenance Factor (TMF)	**0.30 to 0.65**

LENS MATERIALS

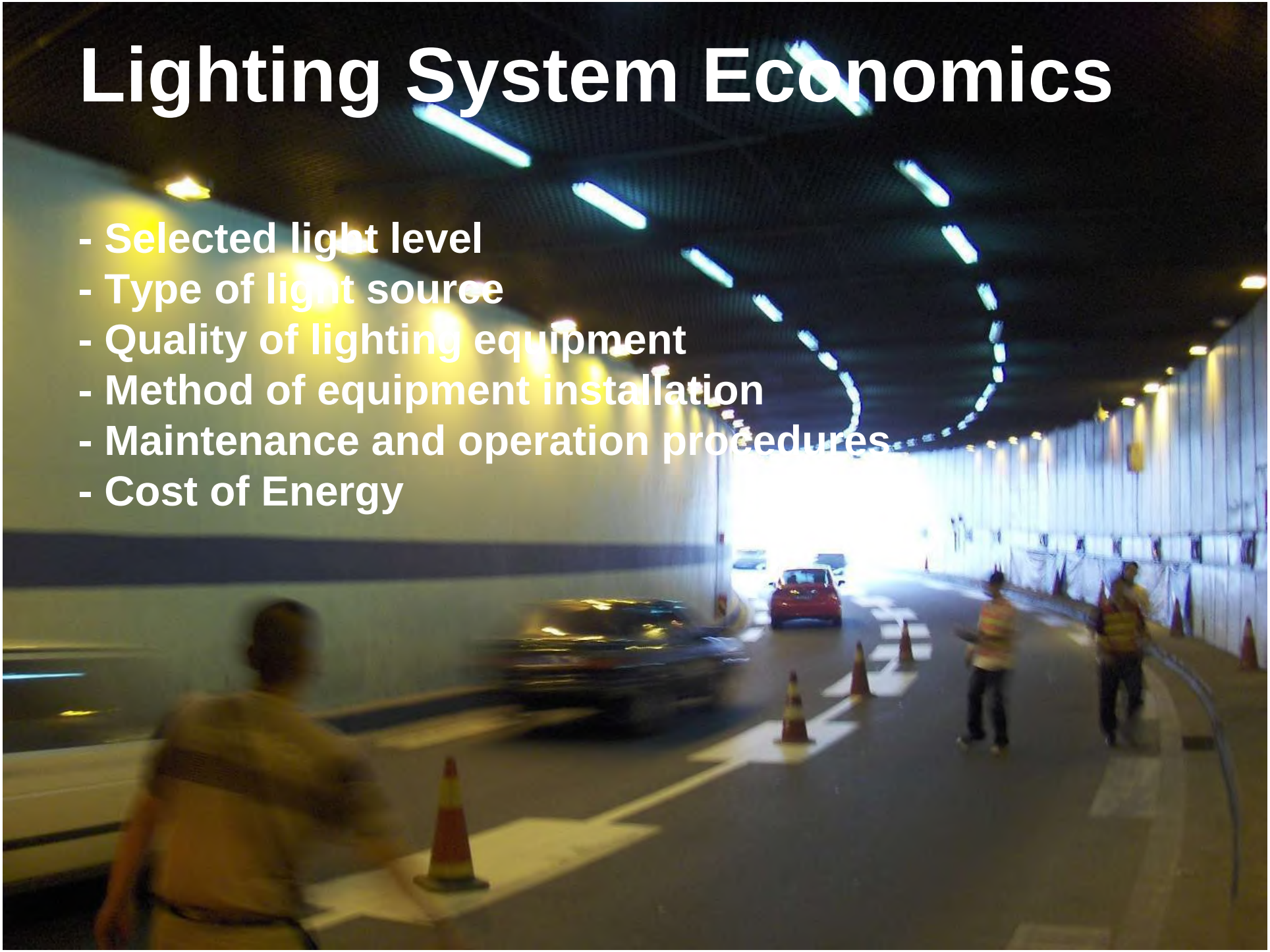
Plastic or Glass?

Plastic Burns.

Glass Doesn’t.

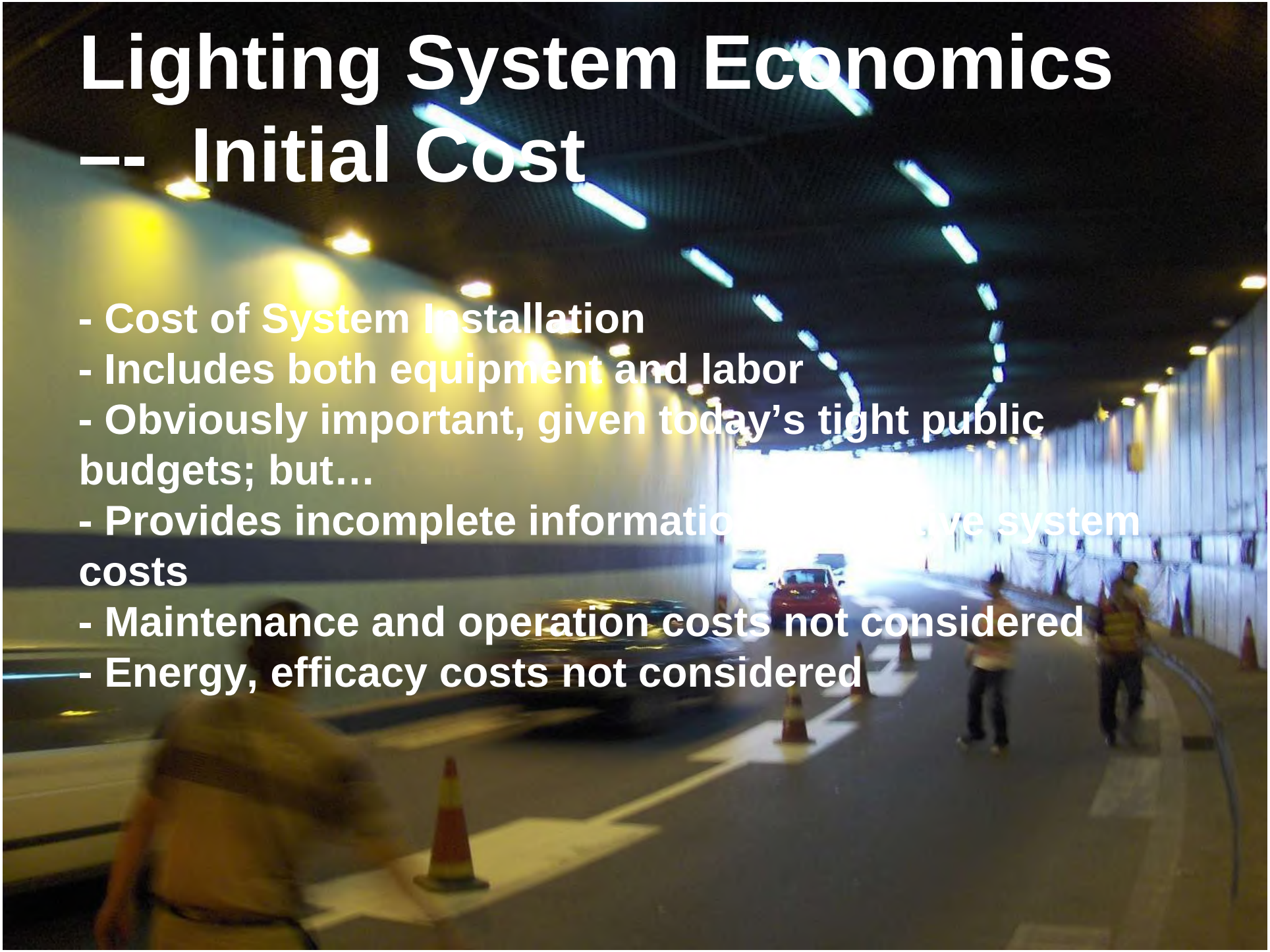
Remember…NFPA 502!!!

Lighting System Economics



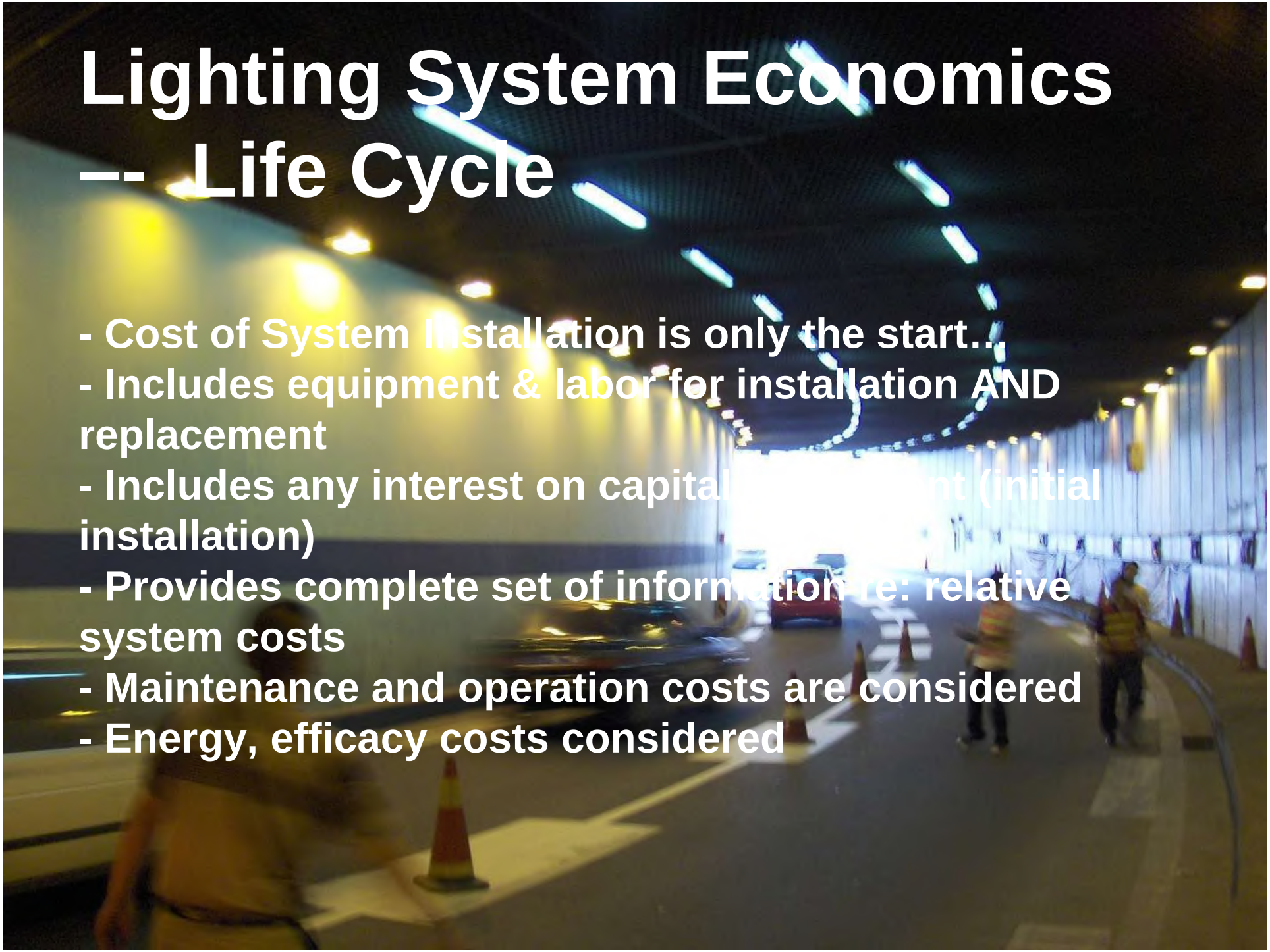
- Selected light level
- Type of light source
- Quality of lighting equipment
- Method of equipment installation
- Maintenance and operation procedures
- Cost of Energy

Lighting System Economics –- Initial Cost



- Cost of System Installation
- Includes both equipment and labor
- Obviously important, given today's tight public budgets; but…
- Provides incomplete information, ve system costs
- Maintenance and operation costs not considered
- Energy, efficacy costs not considered

Lighting System Economics –- Life Cycle



- Cost of System Installation is only the start…
- Includes equipment & labor for installation AND replacement
- Includes any interest on capital [illegible]nt (initial installation)
- Provides complete set of information re: relative system costs
- Maintenance and operation costs are considered
- Energy, efficacy costs considered

TRUE Definition of a Tunnel?

- A Highly Challenging Environment, including…
- Exhaust Fumes Consisting of Hydrocarbons and Other Organics
- High Humidity and Air Salinity
- Structural Vibration
- Salts & Sulfur Corrosives
- Galvanic Coupling Differences (electrolytic ionization)
- Wind Tunneling Effect from large vehicles
- Ingress by Water & Detergents from Washing
- Fire and Life Safety Issues (e.g., NFPA 502)

Highly Challenging Environments

Highly Challenging Environments


The Worst Case….

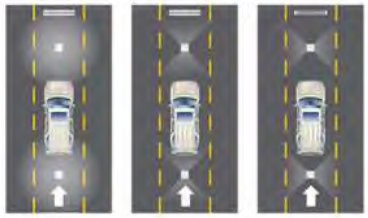
Transportation

Best Practices

Light Distributions For Tunnel Lighting

Tunnel lighting is available in a variety of distribution types—both symmetric and asymmetric—each with specific benefits and applications. When specifying tunnel lighting, thoughtful consideration should be given to the variety of distribution types available. The goal is to maximize the driver's visual experience and illuminate potential obstacles, thereby optimizing their safety and comfort.

Symmetrical-Transverse Lighting

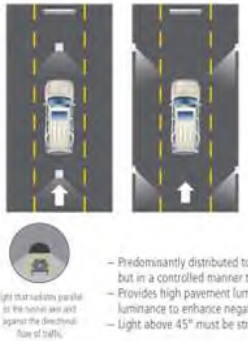


– Uniform luminance throughout tunnel interior
– Generally low contrast values
– Maximizes wall luminances
– Maximizes candlepower to walls

Symmetrical-Axial Lighting

– Uniform luminance throughout tunnel interior
– Generally low contrast values
– Maximizes flux parallel to traffic flow
– Maximizes candlepower to vehicle

Asymmetric– Negative Contrast (Counter-Beam)



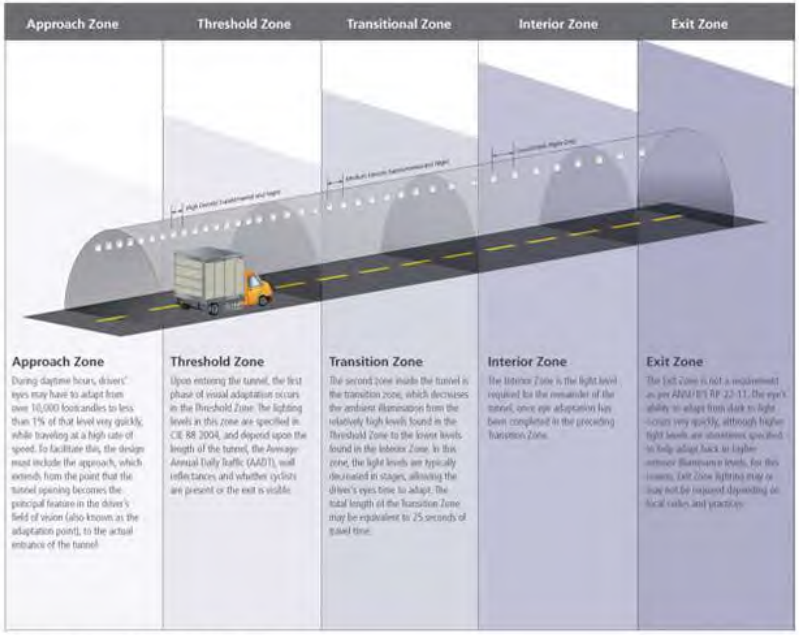
– Predominantly distributed towards the driver, but in a controlled manner to reduce glare
– Provides high pavement luminance, and low object luminance to enhance negative contrast
– Light above 45° must be strictly controlled

Asymmetric– Positive Contrast (Pro-Beam)

– Minimal glare towards the driver
– Primary disruption is in direction of traffic flow
– Provides high object luminance, and low pavement luminance to create positive contrast

Tunnel Lighting Zones

The human eye requires more time to adapt from brightness to darkness than the reverse. For this reason, tunnel lighting must gradually transition to interior light levels. During nighttime hours, the area outside the tunnel is dark, whereas interior levels are similar to those of an illuminated open roadway; making the transition minimal. Tunnel lighting is comprised of distinct zones, each with unique lighting needs:



Approach Zone

During daytime hours, drivers' eyes may have to adapt from over 10,000 footcandles to less than 1% of that level very quickly, while traveling at a high rate of speed. To facilitate this, the design must include the approach, which extends from the point that the tunnel opening becomes the principal feature in the driver's field of vision (also known as the adaptation point), to the actual entrance of the tunnel.

Threshold Zone

Upon entering the tunnel, the first phase of visual adaptation occurs in the Threshold Zone. The lighting levels in this zone are specified in CIE 88 2004, and depend upon the length of the tunnel, the Average Annual Daily Traffic (AADT), wall reflectances and whether cyclists are present or the exit is visible.

Transition Zone

The second zone inside the tunnel is the transition zone, which decreases the ambient illumination from the relatively high levels found in the Threshold Zone to the lower levels found in the Interior Zone. In this zone, the light levels are typically decreased in stages, allowing the driver's eyes time to adapt. The total length of the Transition Zone may be equivalent to 25 seconds of travel time.

Interior Zone

The Interior Zone is the light level required for the remainder of the tunnel, once eye adaptation has been completed in the preceding Transition Zone.

Exit Zone

The Exit Zone is not a requirement as per ANSI/IES RP-22-11. The eye's ability to adapt from dark to light occurs very quickly, although higher light levels are sometimes specified to help adapt back to higher exterior illuminance levels. For this reason, Exit Zone lighting may or may not be required depending on local codes and practices.

Tunnel Lighting: Additional Considerations

Flicker Effect

In addition to lighting each zone of the tunnel appropriately, the lighting design must mitigate the flicker effect caused by the interaction of vehicular speed and luminaire spacing. Flicker frequencies of 10 to 60 flashes per second can cause headaches, eye strain and seizures.

Redundant Circuitry

Kenall's tunnel luminaires are also engineered with redundant circuitry to ensure that if a circuit or transformer fails, there will be an adequate amount of light delivered to the space. In addition, a specified number of fixtures can be dedicated to an emergency circuit, enabling them to remain on should more than one circuit or transformer fail.

Vibration Testing

Vehicles traveling at a high rate of speed also cause repeated vibration that can negatively impact luminaires. As a result, fixtures specified for this environment must be tested to ensure the integrity of the fixture is maintained when subject to repeated vibration. Select Kenall transportation luminaires are tested to ANSI C136.31-2001 standards, ensuring that they are a strong tunnel lighting solution.

Transportation

Listings & Descriptions

Limitations of Wet and Hosedown Ratings – UL Standards

UL standards for wet location ratings simulate an outdoor rain condition. UL standards for type 4 or NEMA 4 "hosedown" ratings use a 1-inch diameter fire hose nozzle delivering 65 gallons of water per minute. Various conditions might dictate that a fixture requires a rating better than a wet location label, but not NEMA 4. These conditions typically exist in washdown applications where hosed water or cleaning agents will be directed at the fixture.

Benefits of Ingress Protection Ratings – IEC standards

The IP water rating of "5," described in IEC Standard 598, provides an intermediate step between the rain rating and the NEMA 4 rating. It also provides an internationally accepted standard which can be used to evaluate fixtures or any other electrical equipment, and the test can be performed by an independent third-party testing agency for verification. Underwriters Laboratories in Northbrook, Illinois tests to the IEC standard.

Dust-tight Protection

An additional test criteria that can be applied to fixtures is the ability to exclude solid matter. The IP solid rating of "6" (IP6_) means the fixture will be dust tight. The specified test requires that the fixture be placed in a circulating talc atmosphere for 3 hours. The particle size of the talc ranges from one to 75 microns, and the fixture is placed under negative pressure in an attempt to draw the talc into the fixture. No talc should be found inside the fixture after this test.

The Importance of Recognized Standards & Independent Testing

Lighting manufacturers that claim a hosedown rating other than NEMA or IP are not testing to recognized standards and have not had the tests confirmed or audited by an independent testing agency.

Beware of statements such as "Tested to 75psi at 1 inch." No reference is made to the volume of water that is leaving the nozzle and impacting the product. In fact, high nozzle pressures typically have low water volumes because the nozzle is restricting the flow of water, causing the pressure in the hose to increase and minimizing the amount of water leaving the nozzle.

Regardless of the hose pressure, any water volume less than 3.3 gal/minute is less severe than the IP_5 test. The most relevant characteristics of hosedown ratings are the diameter of the nozzle and the flow rate of the water. The following chart shows the test characteristics for various Standards.

What are IEC Standards?

IEC Standards are international standards that many European countries adopt as their national standard. North America has traditionally adopted UL standards. U.S. product manufacturers initially designed their products to IEC standards for sale overseas, but are finding them increasingly useful in North America.

Measurement	IP_4	IP_5	IP_6	NEMA4	Marine
Standard	IEC 60598	IEC 60598	IEC 60598	NEMA250	UL 595
Nozzle diameter	.016" (.4 mm)	.25" (6.3 mm)	.5" (12.5 mm)	1.0 inches	1.0 inches
Flow rate	2.65 gal/min (.7 l/min)	3.3 gal/min (12.49 l/min)	26.4 gal/min (100 l/min)	65 gal/min	115 gal/min
Nozzle pressure	—	30 kN/sq m	100 kN/sq m	—	15 psi
Distance	Semi circular apparatus	8-10 ft	8-10 ft	10-12 ft	10 ft
Duration	20 min	15 min	3 min	5 min	5 min

Vibration Testing

ANSI 136.31-2001 details the American National Standard for Roadway Lighting Equipment- Luminaire Vibration. Test criteria, designed to simulate wind- and traffic-induced vibration, recommends that luminaires with die-cast, marine-grade aluminum housings used in bridge and overpass applications be tested at specific acceleration intensities. Select Kenall LuxTran™ luminaires are independently tested for vibration and shock according to ANSI standards, ensuring their ability to withstand the challenges of these potentially damaging environments.

Example:

IP65 — DEGREES OF PROTECTION INDICATED BY THE FIRST CHARACTERISTIC NUMERAL

Numeral	Short Description	Brief details of objects which will be "excluded" from the enclosure
0	Non-protected	No special protection
1	Protected against solid objects greater than 50 mm	A large surface of the body, such as a hand (but no protection against deliberate access). Solid objects exceeding 50 mm in diameter.
2	Protected against solid objects greater than 12 mm	Fingers or similar objects not exceeding 80 mm in length. Solid objects exceeding 12 mm in diameter.
3	Protected against solid objects greater than 2.5 mm	Tools, wires, etc. in diameter or thickness greater than 2.5 mm. Solid objects exceeding 2.5 mm in diameter.
4	Protected against solid objects greater than 1.0 mm	Wires or strips of thickness greater than 1.0 mm. Solid objects exceeding 1.0 mm in diameter.
5	Dust-protected	Ingress of dust is not totally prevented but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment.
6	Dust-tight	No ingress of dust

IP6 — DEGREES OF PROTECTION INDICATED BY THE SECOND CHARACTERISTIC NUMERAL

Numeral	Short Description	Brief details of objects which will be "excluded" from the enclosure
0	Non-protected	No special protection
1	Protected against dripping water	Dripping water (vertically falling drops) shall have no harmful effect.
2	Protected against dripping water when tilted up to 15°	Vertically dripping water shall have no harmful effect when tilted up to 15° when the enclosure is tilted at any angle up to 15° from its normal position.
3	Protected against spraying water	Water falling as a spray at an angle up to 60° from the vertical shall have no harmful effect.
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effect.
5	Protected against water jets	Water projected by a nozzle against the enclosure from any direction shall have no harmful effects.
6	Protected against heavy seas	Water from heavy seas or water projected in powerful jets shall not enter the enclosure in harmful quantities.
7	Protected against the effects of immersion	Ingress of water in a harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time.
8	Protected against submersion	The equipment is suitable for continuous submersion in water under conditions which shall be specified by the manufacturer. NOTE – Normally, this will mean that the equipment is hermetically sealed. However with certain types of equipment it can mean that water can enter but only in such a manner that it produces no harmful effects.

IP64 IP65 IP66 — When you see these symbols you will know the Kenall luminaire has been tested and certified to either the IP64, IP65 or IP66 standard respectively.

IEC

Certified Performance

- Ensures that the selected tunnel fixture has been independently test and certified to deliver all the main aspects of the fixture performance claimed.
- Ensures that the specifier and end-user will get the appropriate and required performance needed for transportation lighting fixtures in harsh, demanding and environmentally challenging environments.
- It means going beyond existing industry fixture specs and typical features, many of which don't guarantee the product will satisfy its ultimate intended purpose
- Luminaires include 10-Year Warranty!!

Certified Performance

UL/CUL Listed—The UL symbol signifies that Underwriter's Laboratory (UL) has determined that a manufacturer has demonstrated the ability to produce a product complying with UL's requirements with respect to specific risk, performance under specific conditions, compliance with regulatory codes and specified standards, or any other conditions as determined by UL.

ETL—A product bearing the ETL Listed Mark is determined to have met the minimum requirements of prescribed product safety standards as certified by a Nationally Recognized Testing Laboratory (NTL). The mark also indicates that the manufacturer's production site conforms to a range of compliance measures and is subject to periodic follow-up inspections to verify continued conformance.

IP64—UL Certified IP64 per IEC 60598 ensures that the enclosure is dust-tight and protected against splashing water without any harmful effects.

IP65 — UL Certified IP65 per IEC 60598 ensures that the enclosure is dust-tight and protected against jet streams of water from any direction without any harmful effects.

NSF2— An NSF2 Listing denotes that the luminaire has been evaluated for corrosion resistance, cleanability and the ability of exposed material to withstand normal wear. This supports the infection control standards established by healthcare facilities as it indicates that the luminaire is easy to sanitize.

MIL STD 461F— Military Standards testing measurements cover both radiated and conducted electromagnetic emissions in addition to maximum allowable amounts of emitted energy based on both frequency range and field strength. Luminaires meeting MIL STD 461F pose the lowest possible likelihood of causing EMI-related issues.

CCEA Approved—The City of Chicago Environmental Air (CCEA) rating ensures that the luminaire is inherently airtight. Wiring and/or branch circuit terminations are sealed off and gasketed from the plenum air space. This listing ensures that the luminaire is sealed to limit air flow from the room side to the plenum.

IC RATED — An IC rated fixture must, by definition, "be approved for zero clearance insulation cover by a nationally recognized OSHA testing laboratory", such as Underwriters Laboratory (UL). "IC" is short for Insulation Contact, which means that any housing that bears this rating can make direct contact with ceiling insulation.

ADA Compliant—Although ADA is not specific to lighting, it does impact fixture design by creating standards for wall sconce projection space and hanging light clearance. Section 4.4 of the ADA states that "objects projecting from walls with their leading edges between 27" and 80" above the finished floor shall protrude no more than 4" into walks, halls, corridors, passageways or aisles."

UL 924—UL 924 is UL's Standard for Safety of Emergency Lighting and Power Equipment. UL 924 listed electrical exit signs are tested and given a visibility rating of at least 100 feet, requiring them to be legible from a 100 foot viewing distance in total darkness. The battery backup is tested by UL and must provide at least 90 minutes of emergency operation. Letters must be red or green and at least 6" height with a 3/4" letter stroke.

NFPA101—This National Fire Protection Agency (NFPA) Life Safety Code pertains to egress facilities. The code establishes minimum criteria for the design of egress facilities so as to allow prompt escape of occupants from buildings or, where desirable, into safe areas within buildings.

ISO 5— Suitable for ISO 5, Class 100 Rated Rooms (FED-STD 209E). Measures the number of particles equal to or greater than 0.5 mm in one cubic foot of air. The measurement must not exceed specified particle limits in order for the space to be considered a controlled 'clean room' environment.

K230—The K230 performance standard determines a fixture's ability to restrict the passage or penetration of contaminants when subjected to a prescribed pressure level in either positively or negatively pressurized environments.

IDA Approved (International Dark-Sky Association) — Educational,environmental 501(c)(3) nonprofit dedicated to protecting and preservingthe nighttime environment and our heritage of dark skies through qualityoutdoor lighting.

Certified Performance Listings for Transportation Luminaires

- Ingress Protection (IP) Ratings per IEC 60598
- Intertek / ETL Listed to UL 1598 Standards
- ANSI Luminaire Vibration Standard C136.31
- ANSI Tunnel & Underpass Standard C136.27
- Rated as NEMA 4X Enclosure for Outdoor Use

Ingress Protection (IP Ratings)

- IEC 60598
- “Ingress Protection for Lighting Fixtures”

Ingress Protection

IP65 or IP66

1st number = protection from solid objects

2nd number = protection from water

IP Ratings:
Numerical Assignments & Explanations
Protection From Solid Objects

Example:

IP65

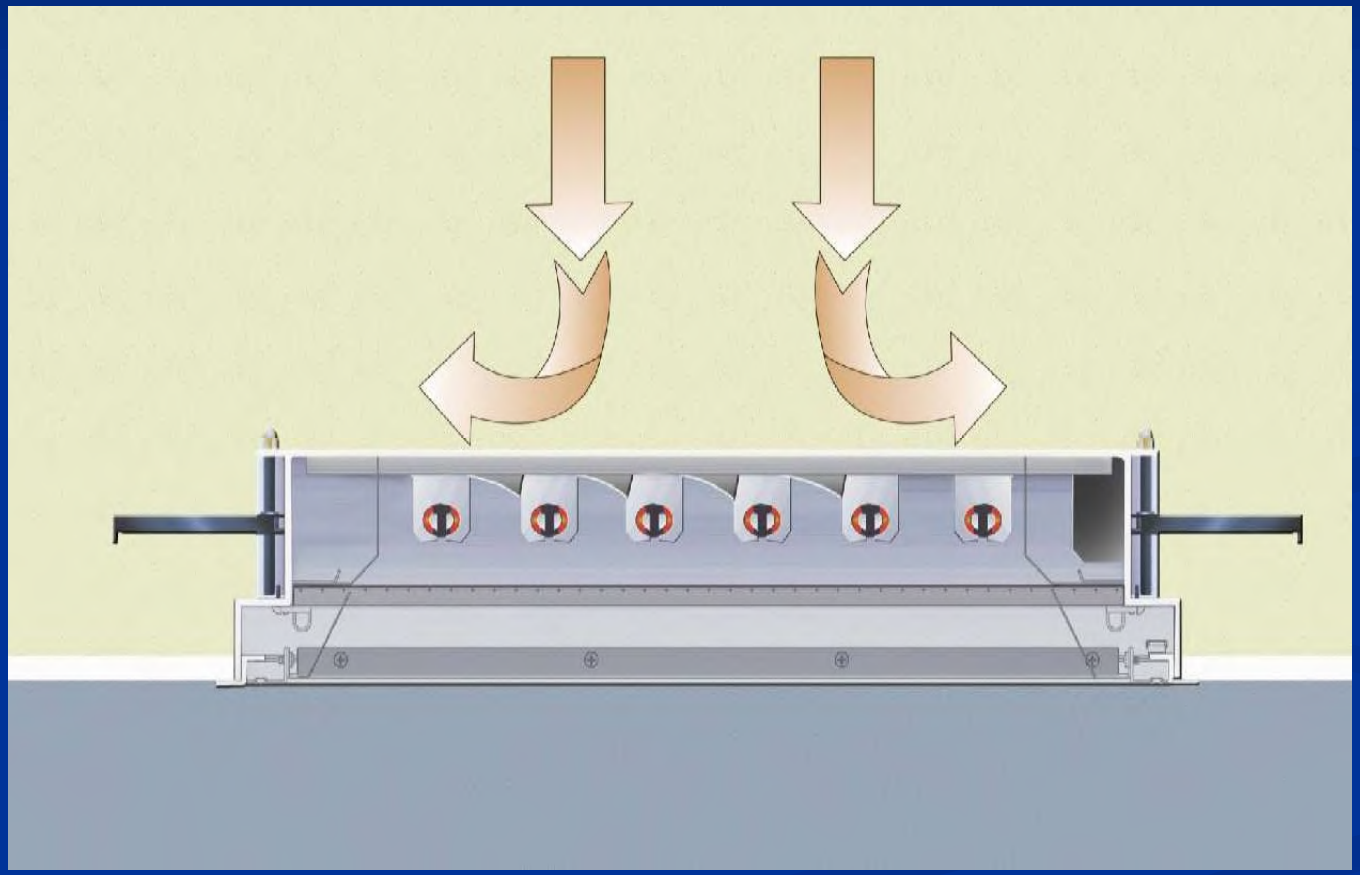
DEGREES OF PROTECTION INDICATED BY THE FIRST CHARACTERISTIC NUMERAL

Numeral	Short Description	Brief details of objects which will be "excluded" from the enclosure
0	Non-protected	No special protection
1	Protected against solid objects greater than 50 mm	A large surface of the body, such as a hand (but no protection against deliberate access). Solid objects exceeding 50 mm in diameter.
2	Protected against solid objects greater than 12 mm	Fingers or similar objects not exceeding 80 mm in length. Solid objects exceeding 12 mm in diameter.
3	Protected against solid objects greater than 2.5mm	Tools, wires, etc., of diameter or thickness greater than 2.5 mm. Solid objects exceeding 2.5 mm in diameter.
4	Protected against solid objects greater than 1.0 mm	Wires or strips of thickness greater than 1.0 mm. Solid objects exceeding 1.0 mm in diameter.
5	Dust-protected	Ingress of dust is not totally prevented but dust does not enter in sufficient quantity to interfere with satisfactory operation of the equipment.
6	Dust-tight	No ingress of dust

Particulate Test

Testing for the IP6 (Dust-tight) portion of rating

No Leakage from Environment



IP Ratings:
Numerical Assignments & Explanations
Protection From Water

IP6

DEGREES OF PROTECTION INDICATED BY THE SECOND CHARACTERISTIC NUMERAL

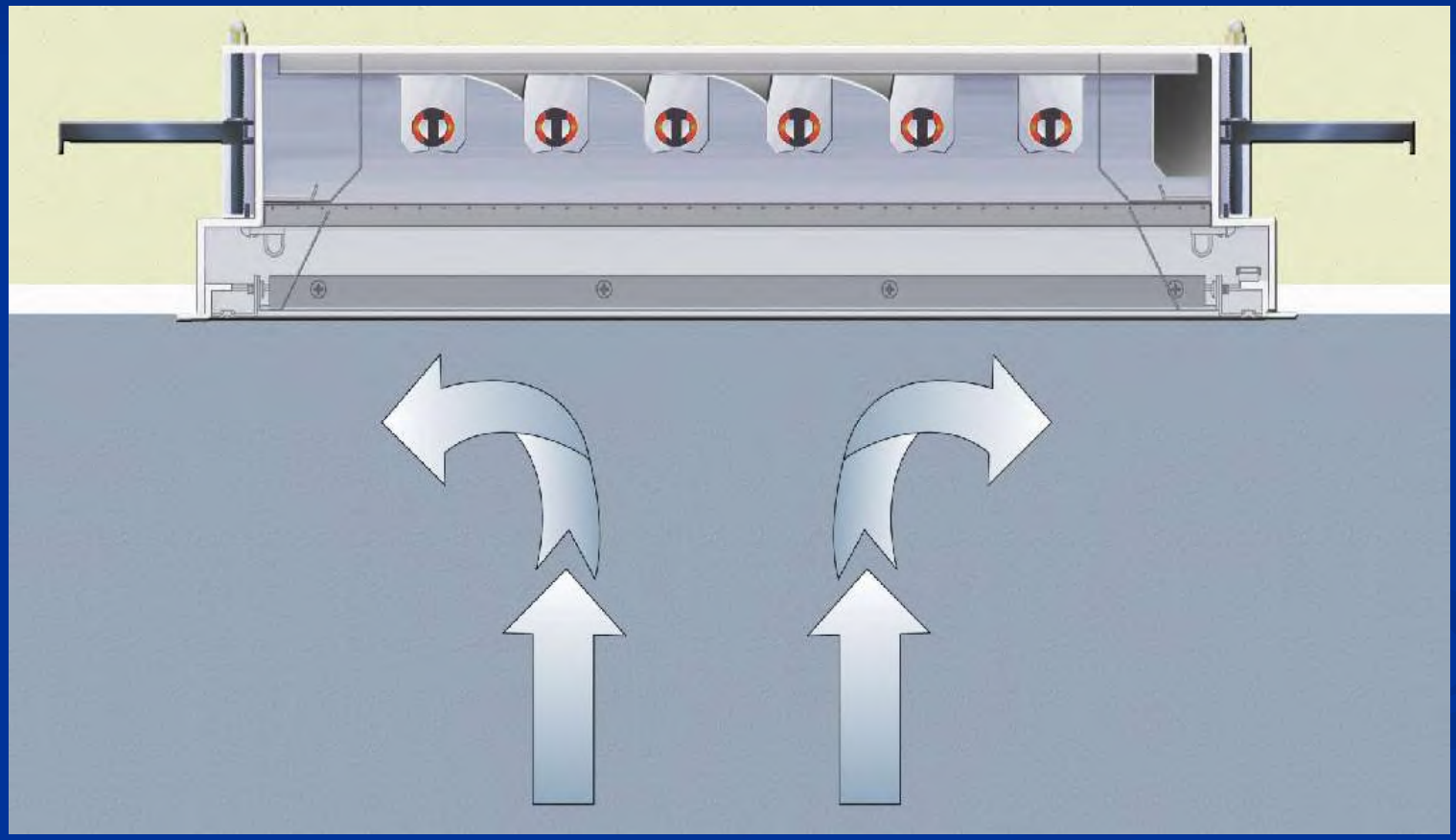
Numeral	Short Description	Brief details of objects which will be "excluded" from the enclosure
0	Non-protected	No special protection
1	Protected against dripping water	Dripping water (vertically falling drops) shall have no harmful effect.
2	Protected against dripping water when tilted up to 15°	Vertically dripping water shall have no harmful effect when tilted up to 15° when the enclosure is tilted at any angle up to 15° from its normal position.
3	Protected against spraying water	Water falling as a spray at an angle up to 60° from the vertical shall have no harmful effect.
4	Protected against splashing water	Water splashed against the enclosure from any direction shall have no harmful effect.
5	Protected against water jets	Water projected by a nozzle against the enclosure from any direction shall have no harmful effects.
6	Protected against heavy seas	Water from heavy seas or water projected in powerful jets shall not enter the enclosure in harmful quantities.
7	Protected against the effects of immersion	Ingress of water in a harmful quantity shall not be possible when the enclosure is immersed in water under defined conditions of pressure and time.
8	Protected against submersion	The equipment is suitable for continuous submersion in water under conditions which shall be specified by the manufacturer. NOTE – Normally, this will mean that the equipment is hermetically sealed. However with certain types of equipment it can mean that water can enter but only in such a manner that it produces no harmful effects.

Water Test

IP65

IP66

No Leakage Into Fixture



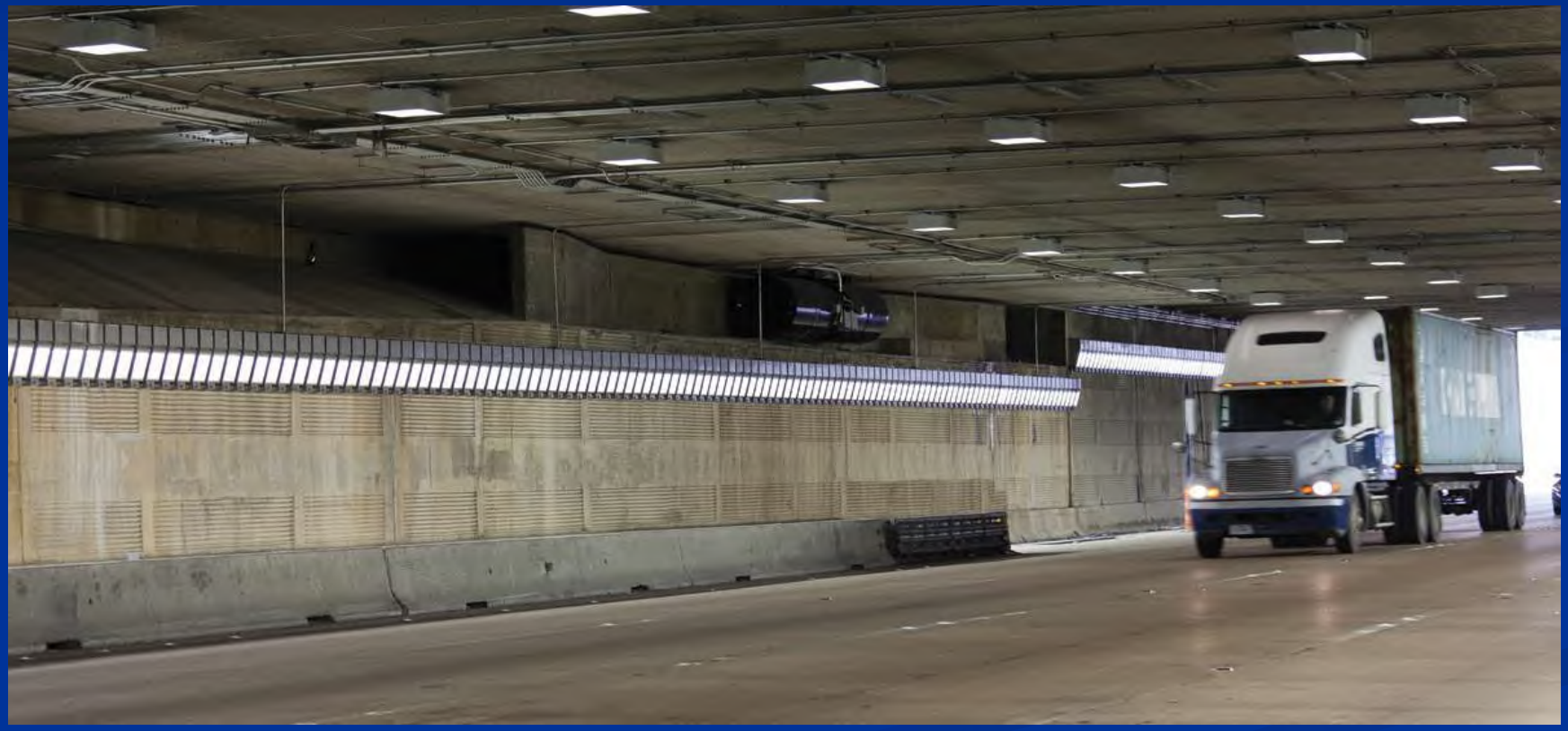
ETL / UL Testing

- Dielectric Voltage Withstand Testing
- Ground Continuity Testing
- Thermal Testing
- IP Testing per IEC 60598
- Typical Listings: UL 1598, UL 1598A, CSA 22.2

ANSI Standard Tunnel and Underpass Fixture Tests

- Temperature Cycling Tests in accordance with ANSI C136.27
- Water Spray Tests (100psi) in accordance with ANSI C136.27
- Vibration Test in accordance with ANSI Standard C136.31
- These Standards provides level of specification protection and integrity that cannot be valued

ANSI C136.31 (3G) Vibration Test



Photometric Testing and Certification

- Photometric Test Lab is NVLAP and IAS Certified
- US DOE LED Lighting Facts & Energy Star Label Partner
- Full LM-79 Testing capability
- Both relative and absolute photometry can be provided
- Will verify with Independent Test Lab Photometry

Corrosion…
Always the Big Question…

- Aluminum Housings…what can one really expect re: lifetime?
- Aluminum alloys typically used
- Re: Aluminum Housings…its all about overall material process
- Pre-treatment and coatings
- What are site's environmental conditions and salinity levels?
- Types of stainless steel used?
- Stainless steel vs. Aluminum?

A Case for Stainless Steel

- 316 Stainless Steel is exempt from salt spray testing because its so robust
- Typical uses include Exhaust Manifolds, Furnace Parts, Heat Exchangers and Jet Engine Parts

- All welds are passivated restoring a uniform chromium oxide film on the materials surface thus eliminating the potential for corrosion of rouging.
- Isolate the housing and the heat sink from galvanic reactions while sealing the fixtures to IP66
- Coordinate mounting arrangements with fixture housing
- *Put it in the spec!!*

When Done Right

Luminaires

Tunnel/Underpass, LED

NEMA 4X

LINEAR LUMINAIRES

PRODUCT FEATURES:

- Wall or ceiling mount, 48“ L
- Continuous or non-continuous
- Up to 80W led; remote or integral
- IES Type I, II, V, & PB/CB optics

LISTINGS:

UL/CUL Listed for Wet Locations.
UL certified IP66 per IEC 60598.
ANSI C136.27, C136.31 compliant.

IP66

Tunnel/Underpass, LED

NEMA 4X

“BOX-TYPE” LED SERIES

PRODUCT FEATURES:

- Wall or ceiling mount
- 2-piece stainless steel housing/door
- Up to 400W led; remote or integral
- IES Type I, II, V, & PB/CB optics

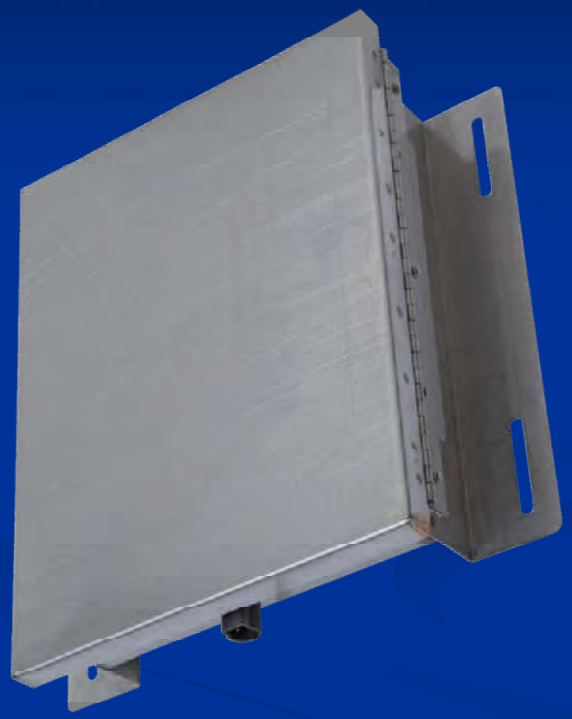
LISTINGS:

UL/CUL Listed for Wet Locations.
UL certified IP66 per IEC 60598.
ANSI C136.27, C136.31 compliant.

IP66

Tunnel/Underpass, LED

NEMA 4X



REMOTE DRIVER OPTIONS/

PRODUCT FEATURES:

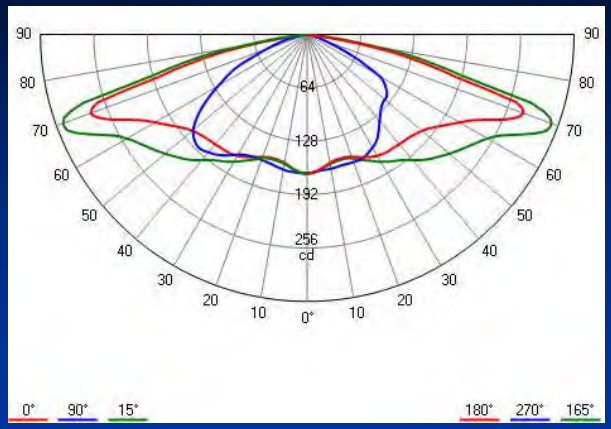
- Wall mount driver cabinet, stainless steel housing/door
- Powers up to six 400W led fixtures
- Powers up to 24 100W led fixtures

LISTINGS:

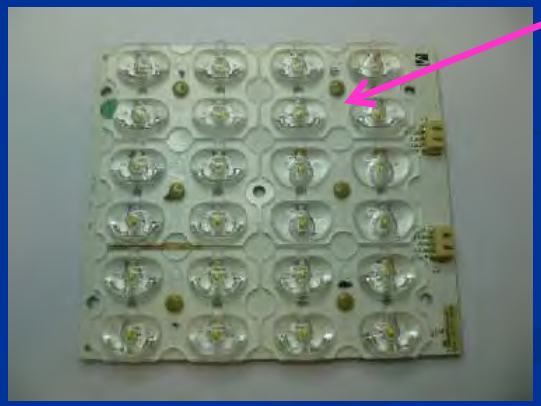
UL/CUL Listed for Wet Locations. UL certified IP66 per IEC 60598.
ANSI C136.27, C136.31 compliant.

IP66

Modular LED System:



- Module:
  - 48 LED Boards → in steps of 4 LEDs
  - Flat MCPCB, Lensed Optic Principle
  - CRI = Minimum 70, Typical
  - Neutral White (WW & CW also available)
  - Cree XP-L LEDs: 107lm/W @700mA*, 96 LEDs
  - Cree XP-L LEDs: 110lm/W @700mA*, 192 LEDs



<u>Lensed Optics</u>

- Multiple LVKs
- Superposition
- Scalable principle
- ***Reduces glare***
- Does manufacturer assemble LED boards

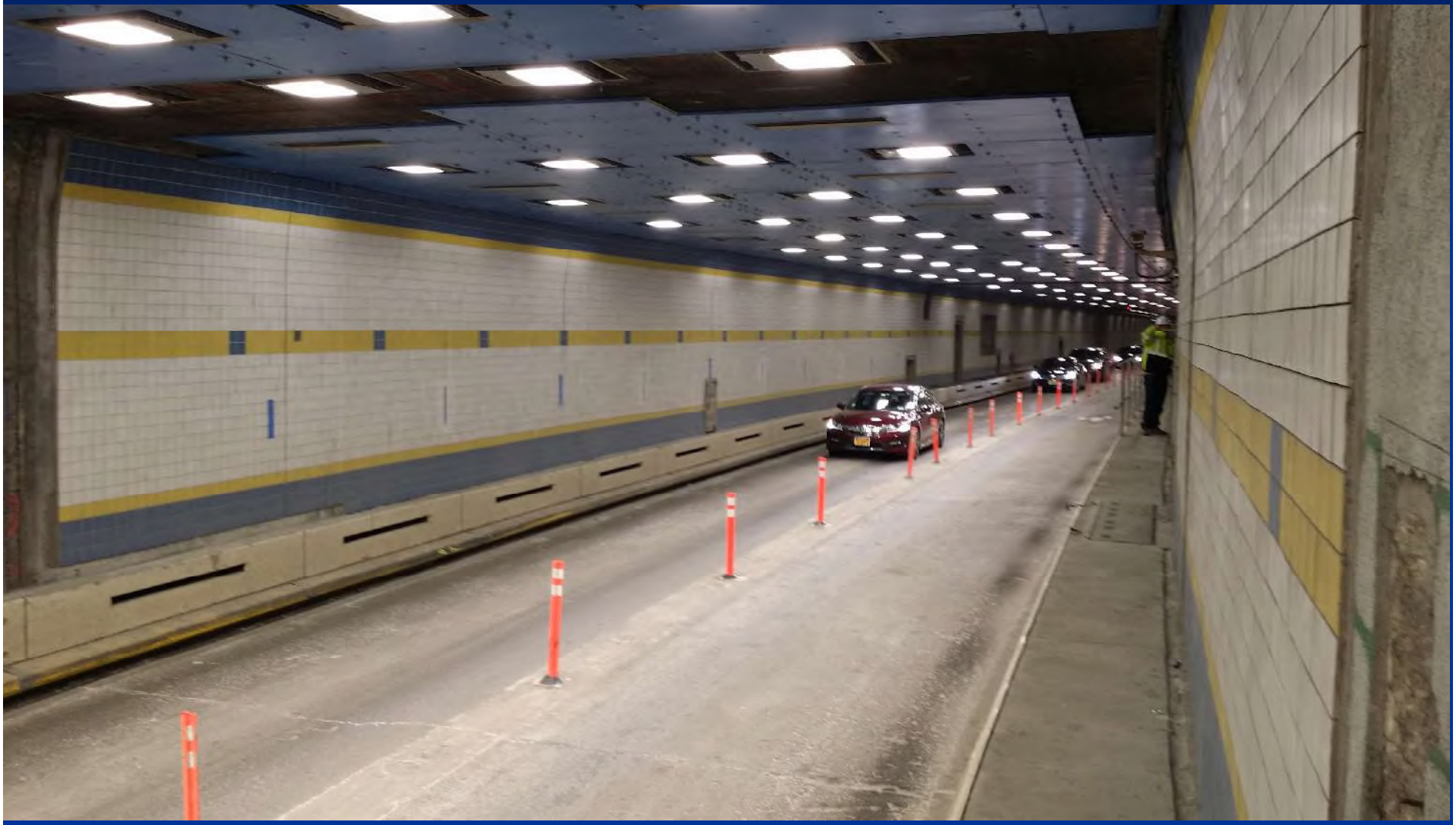
* LED Type Standard, February 2016

Port of Miami Tunnel Project – 2015

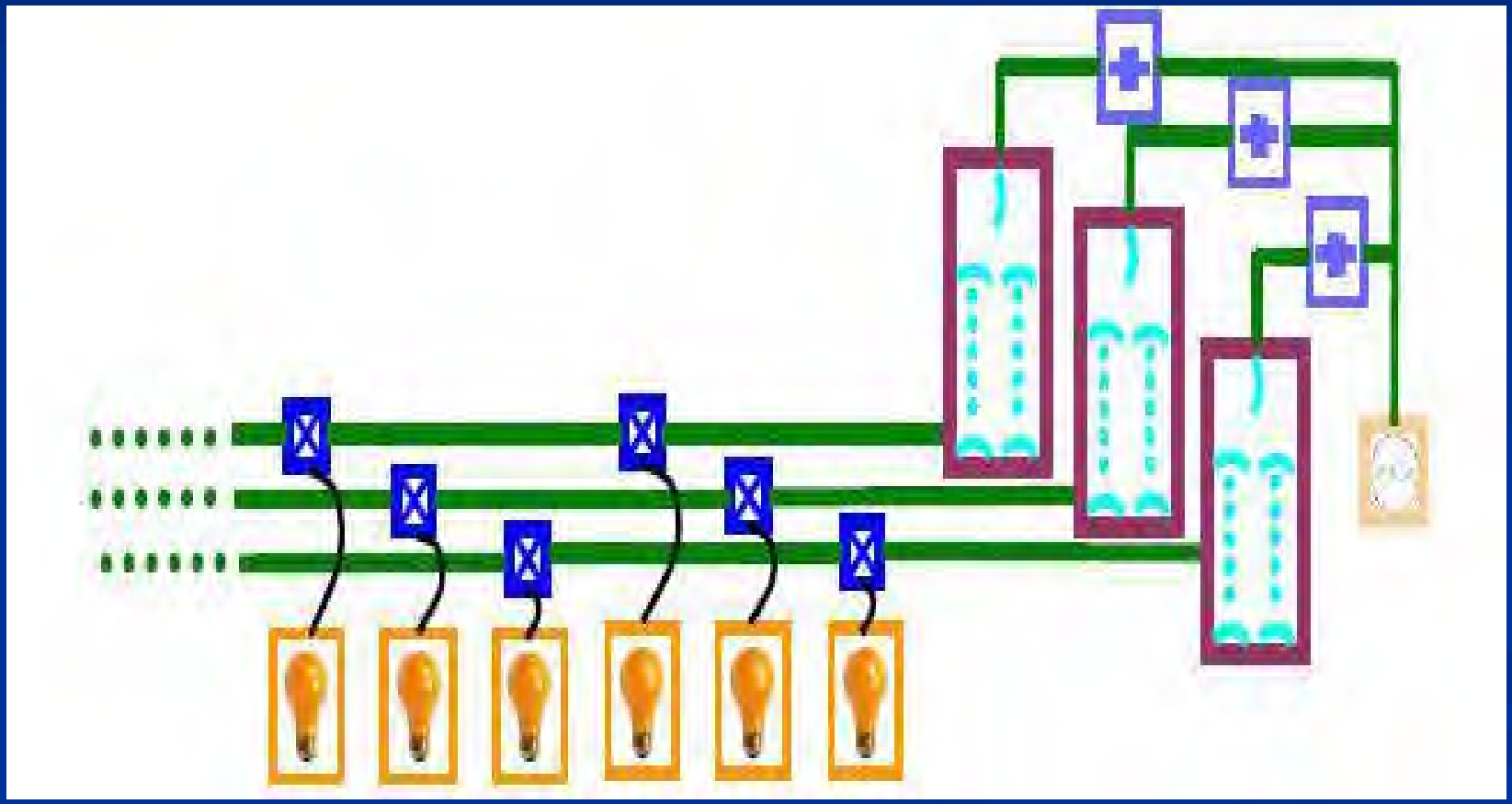
Chesapeake Tunnel Project, VA - 2016

Lytle Tunnel; Cincinnati, OH – 2016

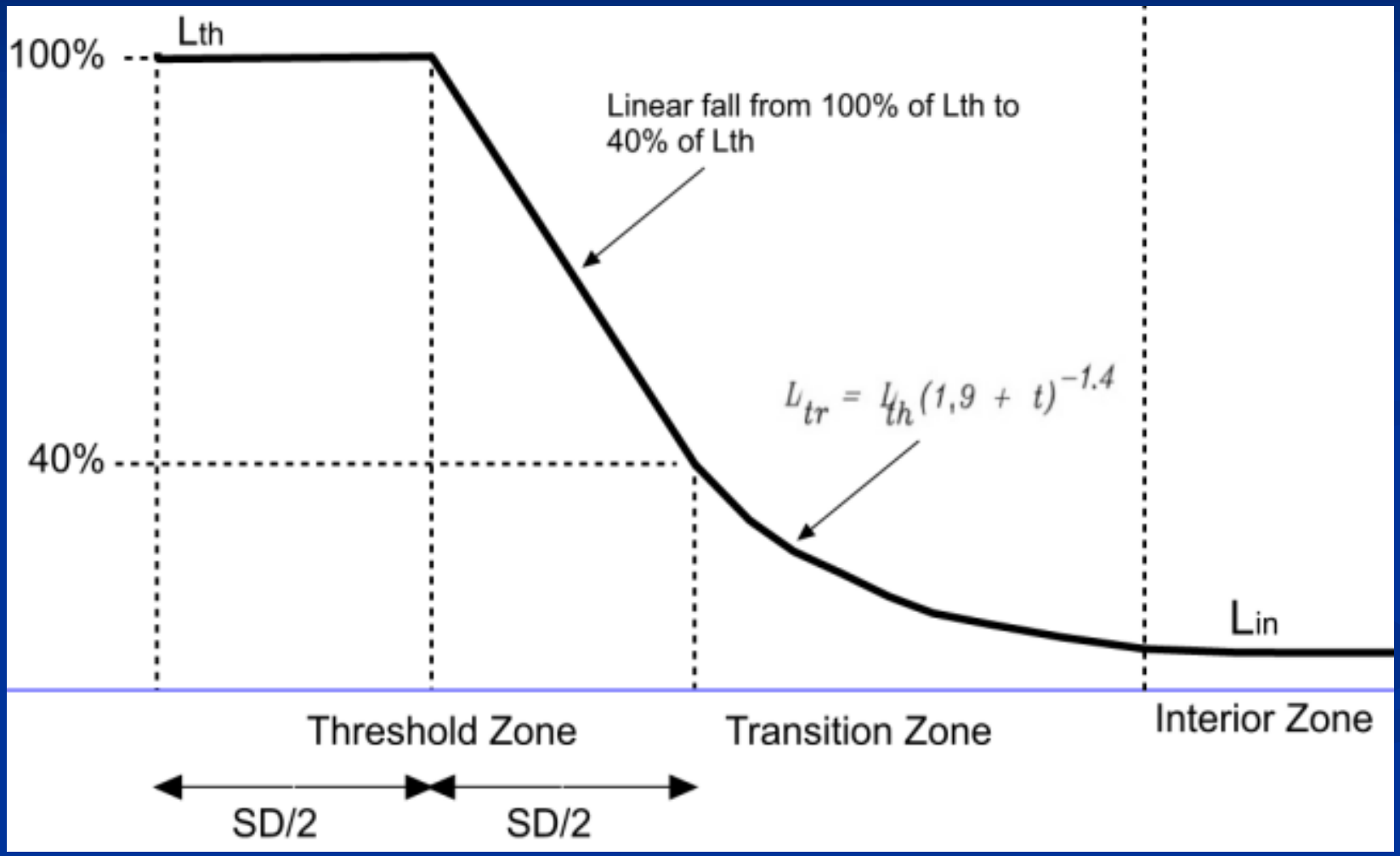
Hugh L. Carey Tunnel; New York, NY – 2017



Controls for Tunnel Lighting Installations; How has LED Lighting Impacted Them?



Controls for Tunnel Lighting Installations; Dimming and Energy Savings?



Relative Influence of Energy Consumption

Length of tunnel	L ≤ 500 m	500 m < L ≤ 3 000 m		L > 3 000 m	
System / Tube	Uni and Bi	Uni	Bi	Uni	Bi
Lighting	Very high	High	Medium	Medium	Small
Ventilation	N.A.	Very small	Medium	Small	High
Safety equipment	Very small	Small	Small	Medium	Medium
Pumps	Small	Small	Small	Small	Small
Auxiliaries	Very small	Small	Small	Medium	Medium

Call to action

- What do you want a manufacturer to do?

One last thing

- Project Services
- Layout and Design
- Quote and Ordering “Check & Balance”
- Palletized and Labeled
- Shipment Tracking
- Installation and Wiring Instructions
- Rebates with LEDs?

FINAL WORD/QUESTIONS