

**A LOGICAL APPROACH TO
ROADWAY LIGHTING DESIGN**

M.G. El Gazzar

"To David Dean for years of inspiration, continuous demand of high quality roadway lighting design, relentless questioning, editing this paper, and for making it readable."

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A LOGICAL APPROACH TO ROADWAY LIGHTING DESIGN

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ABSTRACT:

The roadway lighting design process is of sufficient complexity that a logical and systematic approach is needed. This paper describes such an approach using a flow chart as a guiding tool, with careful attention to critical points in making decisions, quality control, and budgeting time and resources. This approach provides a logical basis for selecting lighting fixtures, fixture mounting heights, setbacks, configurations, and fixture spacing.

Special attention is given to lighting pollution issues with emphasis on solving the problems of glare, urban sky glow, and light trespassing. Illuminance, luminance, and small target visibility calculations methods are discussed. 3D light rendering tools provide a complete picture for the lighting system performance.

Several tables, diagrams, examples, and formulas are included.

INTRODUCTION

Roadway lighting design is changing. There is an increasing understanding of lighting and its influence on safety. There is also an awareness of the all too often negative aspects of lighting on the built environment. We have better tools now - software is available to help perform the massive and complex computations and analysis that is required for even a simple roadway. Manufacturers have and continue to improve lighting products at a rapid rate. The industry is stepping forward to be an advocate for better lighting. The lighting designer has an obligation to “raise the bar” and elevate design performance. The old ways are not good enough.

Very often a person new to roadway lighting design gets overwhelmed with the factors contributing to the design process, the available choices, and the possible solutions. It becomes even difficult to find the starting point. I have tried in this paper to help the designer narrow down the choices and help establish a method for roadway lighting design. This advice does not replace a good text in road way lighting design, or the designer’s research and practice for arriving into an optimum design. This advisory is basically an attempt to focus the designer’s efforts to make good, common sense design decisions.

ROADWAY LIGHTING DESIGN

There are four basic steps to roadway lighting design; an initial study to become familiar with the project and design requirements, selection of the general types of fixtures and poles to be used, locating the fixtures, and performing appropriate computations to assure conformance to design criteria. The more familiar you are with the design requirements the easier it is to select the appropriate fixtures. If you understand the various fixture types and nomenclature used, selecting fixtures is simplified. If the “best” fixtures are selected for the various applications, optimizing the locations of the fixtures and demonstrating compliance with the design criteria is relatively easy. The number of iterations required is minimized.

Figure 1 presents a flow chart that shows the design process, including the design of the power distribution system. Quality control steps are identified.

Initial Study

Study the project including the roadways, the interchanges, etc. and identify the following features:

- Names of the different segments of the project, including streets, ramps, bridges, overpasses, tunnels, etc.
- Identify diverging lanes, converging lanes, abrupt curves, accelerating, and decelerating traffic lanes. These locations will need careful attention.
- Identify segments of the project where the road is categorized as major, collector, and local streets. It is important that you determine the pedestrian crossings locations.
- Identify structures, walls, fences, ditches, water ponds, lakes, or rivers.
- Identify pedestrian walkways, sidewalks and bikeways. They require different lighting criteria.
- Identify any hospitals, residential areas, airports, observatories, industrial, commercial zones or any other critical locations close by.
- Identify public rights of way.
- Identify the elevations of the different roads, ramps, overpass, etc. on the project. This is especially important whether you intend to use high mast fixtures for lighting roads at different elevations (See the Case Study), or if you use offset lighting.
- Determine the width of the different pavements, shoulders, medians, barriers, etc.
- Visit the project site to get a feeling for the area. Is the project an extension of an existing area with existing patterns and/or existing types of fixtures that need to be matched?
- Identify parts where you can use the median for lighting. This might be a good idea provided that it does not cause problems for traffic during maintenance.
- Identify the clear zones where you intend to locate poles. Try to locate the poles behind guardrails, girders, and ditches whenever you can, you might consider fixtures that allows for large setbacks.
- Are there any trees near by? Which kind? How large can they grow? It is important that you know this information; you might consider moving some of the poles, to avoid obscuring the lights, or cutting the trees.
- Talk to the transportation engineers and ask for their comments, ideas, or concerns.
- Listen to the customer's requirements and identify their interests and concerns.
- Establish the lighting criterion for each segment of the projects. Different road classifications have different criterion, so do not treat them the same. We have combined the road way lighting criteria in one table (See Table 1).
- Identify the appropriate Pavement Classification (R1, R2, R3, or R4).

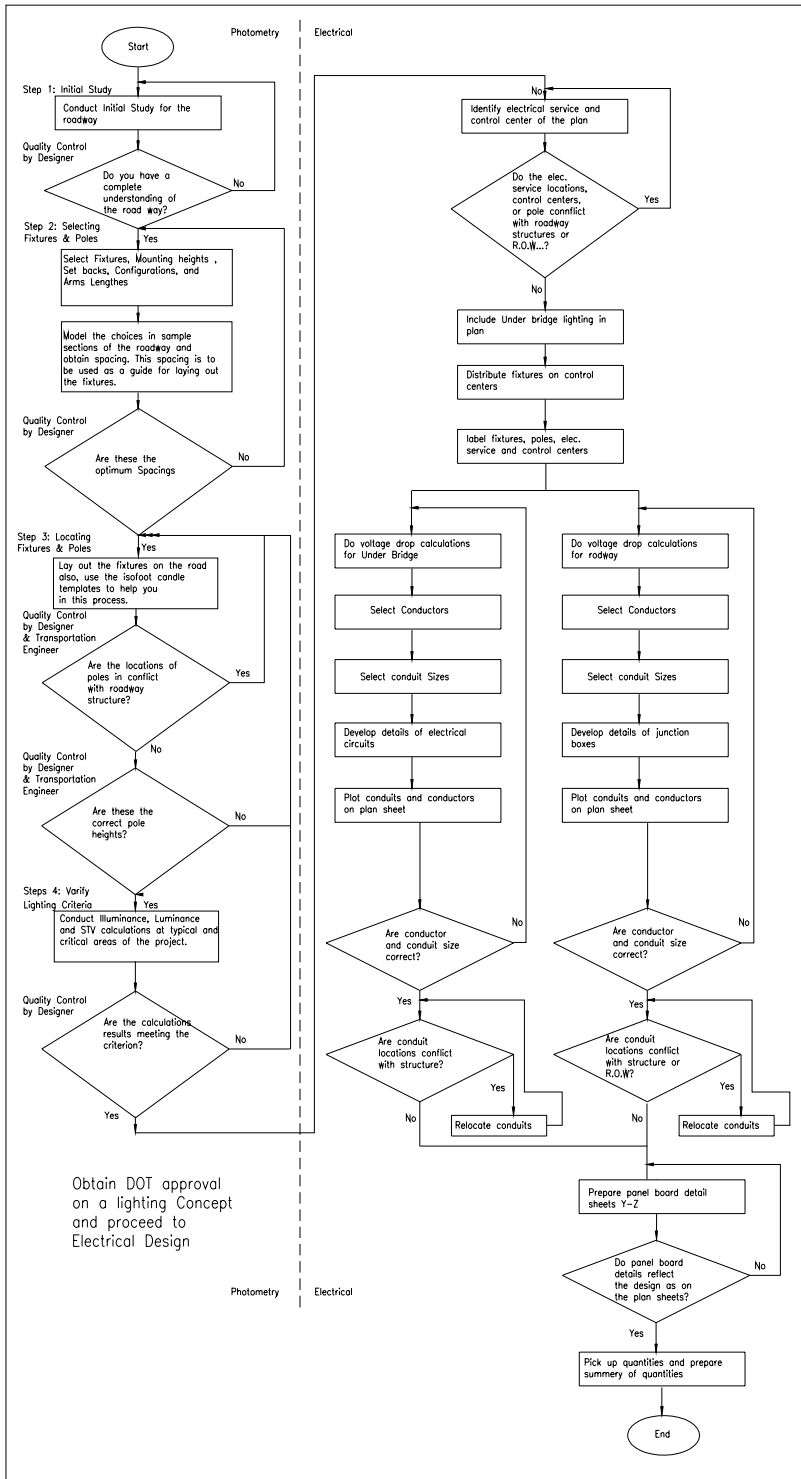


Figure 1
Lighting Design Flow Chart.

**Table 1
Roadway Lighting Design Criteria`**

Road	Pedestrian Conflict Area	Average Luminance L(avg) Cd/m ²	Uniformity Ratio Lavg/Lmin Max. allowed	Uniformity Ratio Lmax/Lmin Max allowed	Veiling Luminance Ratio Lvmax/Lavg Max. allowed	Min Maintained Average Illuminance on Pavement R1 in fc	Min Maintained Average Illuminance on Pavement R2&R3 in fc	Min Maintained Average Illuminance on Pavement R4 in fc	Uniformity Ratio Eavg/Emin	STV Criteria Weighting Average VL	LavgCd/m ² Median >=7.3 m	LavgCd/m ² Median <7.3 m
Freeway Class A		0.6	3.5	6	0.3	0.6	0.9	0.8	3	3.2	0.5	0.4
Freeway Class B		0.4	3.5	6	0.3	0.4	0.6	0.5	3	2.6	0.4	0.3
Expressway	High	1	3	5	0.3	1	1.4	1.3	3	3.8	0.5	0.4
Expressway	Medium	0.8	3	5	0.3	0.8	1.2	1	3			
Expressway	Low	0.6	3.5	6	0.3	0.6	0.9	0.8	3			
Major	High	1.2	3	5	0.3	1.2	1.7	1.5	3	4.9	1	0.8
Major	Medium	0.9	3	5	0.3	0.9	1.3	1.1	3	4	0.8	0.7
Major	Low	0.6	3.5	6	0.3	0.6	0.9	0.8	3	3.2	0.6	0.6
Collector	High	0.8	3	5	0.4	0.8	1.2	1	4	3.8	0.6	0.5
Collector	Medium	0.6	3.5	6	0.4	0.6	0.9	0.8	4	3.2	0.5	0.4
Collector	Low	0.4	4	8	0.4	0.4	0.6	0.5	4	2.7	0.4	0.4
Local	High	0.6	6	10	0.4	0.6	0.9	0.8	4	2.7	0.5	0.4
Local	Medium	0.5	6	10	0.4	0.5	0.7	0.6	4	2.2	0.4	0.3
Local	Low	0.3	6	10	0.4	0.3	0.4	0.4	4	1.6	0.3	0.3

Beside the RP-8-00 you may find useful information in other publications such as the AASHTO informal guide for roadway lighting, and publications from your state department of transportation

Selecting Fixtures and Poles

“THE GOAL IS AN OPTIMUM FIXTURE ON AN OPTIMUM POLE”

Although there are hundreds of fixtures available in the market, you can simplify and optimize the selection process, by selecting only fixtures that are designed for roadway application. The performance characteristics of each fixture and lamp are unique. The characteristics may be obtained from the manufacturer graphically or as an electronic file.

Roadway fixtures are classified, Figure 2, as non-cutoff, semi-cutoff, cutoff, and full-cutoff, based on the amount of light permitted above the horizontal. A full cutoff fixture permits no light at or above the horizontal, which minimizes lighting pollution such as Urban Sky glow.

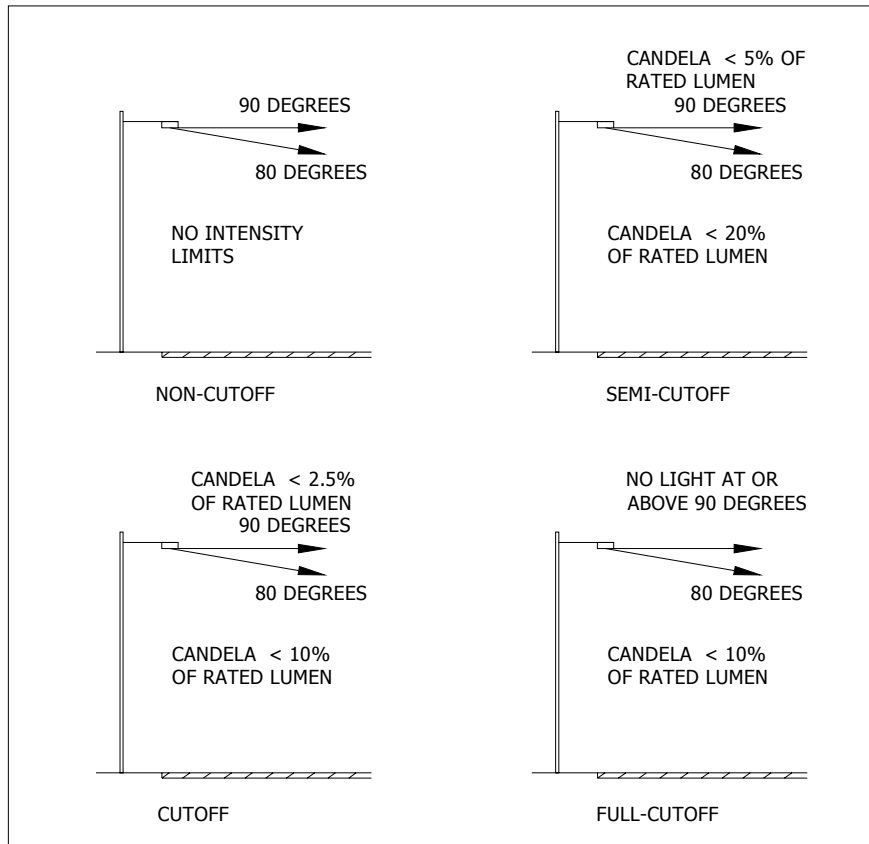


Figure 2
Roadway Fixture Cutoff Classification

Many jurisdictions are moving towards limiting fixtures used on roadways to cutoff or full cutoff. From the designer's perspective it just produces a better design if you adopt that as a standard.

Select the fixtures to be of cutoff-type or full cutoff with zero tilt, and zero roll angles to minimize glare, and urban sky glow. When luminaires are tilted, or rolled upward, they can emit light above the horizontal.

Fixtures for roadway applications are further classified as Short, Medium, and Long. This classification essentially relates the type of fixture, the spacing, and the mounting height:

- Short - the maximum luminaire spacing is generally less than 4.5 times the mounting height.
- Medium - the maximum luminaire spacing is generally less than 7.5 times the mounting height.
- Long - the maximum luminaire spacing is generally less than 12 times the mounting height.

The IESNA Lighting Handbook Reference & Applications presents a more exact definition of vertical light distributions.

Fixtures for roadway applications are classified as type I, II, III, or IV (Figure 3). Notice the relationships between different fixtures types and width of the road. Type I fixtures are generally used for narrow roadways. Type IV is used for wide, multi-lane roads.

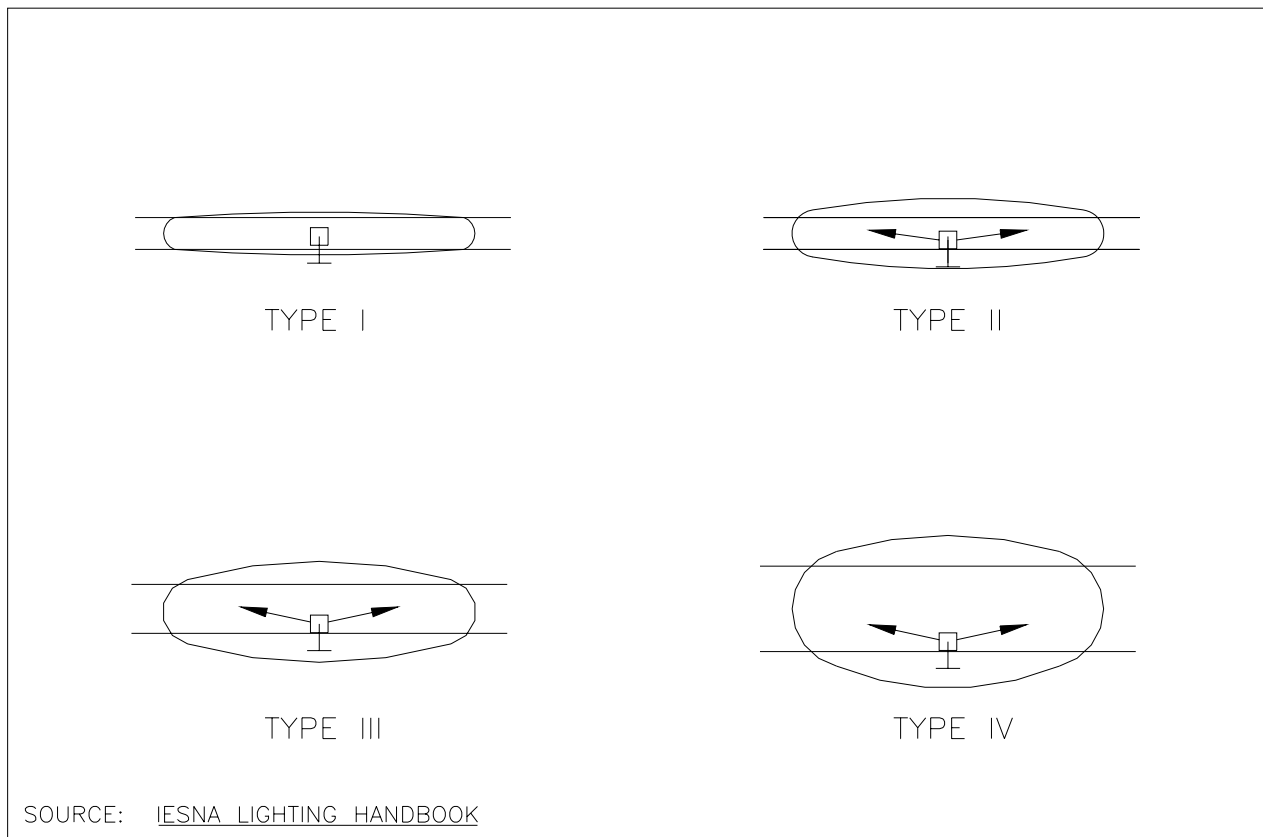


Figure 3
Roadway Fixture Type Classification

Now that we understand the roads and have selected the fixtures, we can select the mounting poles. Although we have taken several steps in the design process, we will have to confirm the correctness of our selections later.

The primary selection of the poles will depend on several factors, such as width of the road, and the location of the project:

- As a rule of thumb use shorter poles for narrower roads, taller poles for wider roads. Use short poles close to residential areas.
- Select poles designed for roadway applications.
- For safety, and unless poles are behind walls, guard rails, or ditches, select poles of break-away design, even if the poles will be located well off the road.
- Select the poles to withstand the wind force in the project area.
- Pole foundation and/or mounting design must be considered carefully and coordinated in the overall design of the roadway, bridges, etc.
- Select poles aesthetically appealing, and suitable for the project, especially in down town, and historical areas.
- Consider high power factor fixtures and ballasts.

The mounting height of a fixture is very important. It can affect the results of the design considerably. The horizontal illumination is inversely proportional to the square of the vertical distance, as measured from the light source. In general the relationship is expressed as;

$$E = (I \cos^3 \theta) / h^2 \quad \text{“ The Cosine Cubed Law”}$$

Where: E = illuminance

I = source intensity

H = vertical distance from the source

θ = the angle as measured from the vertical to the incident ray.

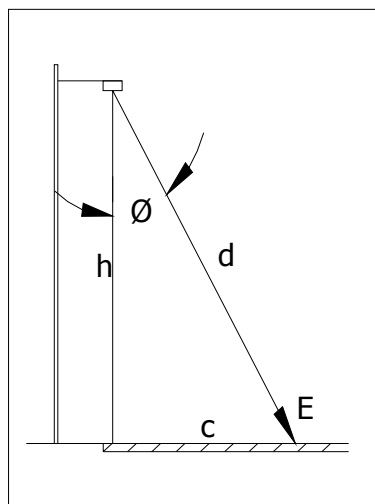


Figure 4
The Cosine Cubed Law

Notice that there can be a difference between the height of a pole and the mounting-height of the fixture. If a 35-foot-high pole is placed on a 4-foot-high wall, the mounting height is 39 foot.

As with everything, there are tradeoffs to be made in lighting design. Pole height impacts the fixture spacing. Shorter poles, a relative term, are less costly and typically use lower wattage lamps than higher poles, but more fixtures are needed to obtain the required uniformity.

Also notice that when you illuminate roads at different elevations from one fixture (or groups of fixtures) you should expect different levels of illumination at the different road surfaces. From the Cubed Cosine Law above, and considering the simplified case where $\theta = 0$, we can say that the illuminance at two different elevations E_1 and E_2 , if illuminated from the same source, can be calculated from:

$$E_1/E_2 = h_2^2/h_1^2$$

If, for example, h_1 is 50 feet and h_2 is 20 feet, then the $E_1/E_2 = (20)^2/(50)^2 = 0.16$. This means that the illuminance at the lower roadway is only 16 percent of the upper roadway. This is particularly important when high mast fixtures are used to illuminate roadways or ramps at different elevations. A ramp is continuously changing elevation, so the lighting at the lower part of the ramp could be very different from the lighting on the upper part of the ramp, if the lighting is from the same source.

Again, the fixture manufacturers give you guidance on the appropriate fixture to use for various mounting heights.

Case Study

At an interchange, a secondary road passes 25 feet above a multi-lane divided highway. A long curved ramp climbs from the highway level to a height of 50 feet and then descends down to the secondary road level.

A conceptual design of the interchange was prepared using high mast fixtures mounted on 100-foot-high poles. However, a 3D rendering of the interchange produced both very bright and completely dark areas on the ramp. Three problems were identified:

1. The level of illuminance was significantly different from one road to another.
2. The level of illuminance was significantly different throughout the climb and ascent of the ramp.
3. The higher roadway caused shadows on the lower roadway.

Figure 5 shows the 3D rendering of the ramp.

Figure 6 shows a plan and an elevation. On the plan you will find the statistical zones, point-by-point illuminance levels, in footcandles (fc), on the ramp, on the secondary roadway, and on the main roadway. The dashed lines relate the statistical zones on the plan to the ramp, and the roadways in the elevations. Also, the source of light at the top of the high mast in the elevation is connected to the projection of the 0.2-footcandle templates in the elevation.

The iso-footcandle template of 0.2 fc appears as a perfect circle on the plan and indicates illuminance levels of higher than 0.2 fc inside the circle; however we have to remember two basics pieces of information:

1. The iso-footcandle template shows the performance on the road surface of the main roadway (elevation of 0 foot).
2. The light from the high mast fixture forms a cone of light not a cylinder.

So, at higher elevations, although the ramp appeared within the iso-footcandle template in the plan view, parts of the ramp are outside of the light cone in the elevation view.

The solution to the problem was to move the high mast away from the ramp, and to use 35-foot-high poles with 150 watts full-cutoff fixtures to illuminate the ramp. The main roadway and the secondary roadways were lit using high masts with various distributions of fixtures and located such that the lighting criteria was achieved on each roadway. Illuminance was calculated considering the slope of the ramp to verify that the lighting design criteria were also met for the ramp.

Table 2 summarizes the results of the calculations.

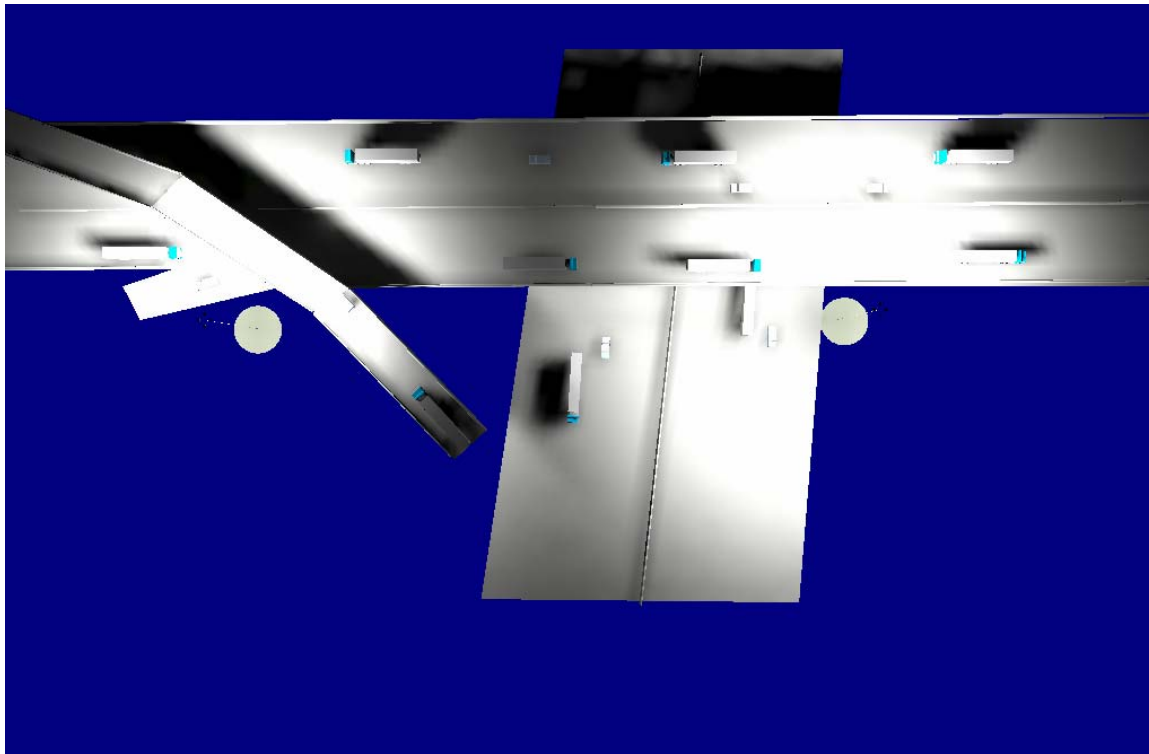


Figure 5-A
Rendering (The Problem)– Case Study

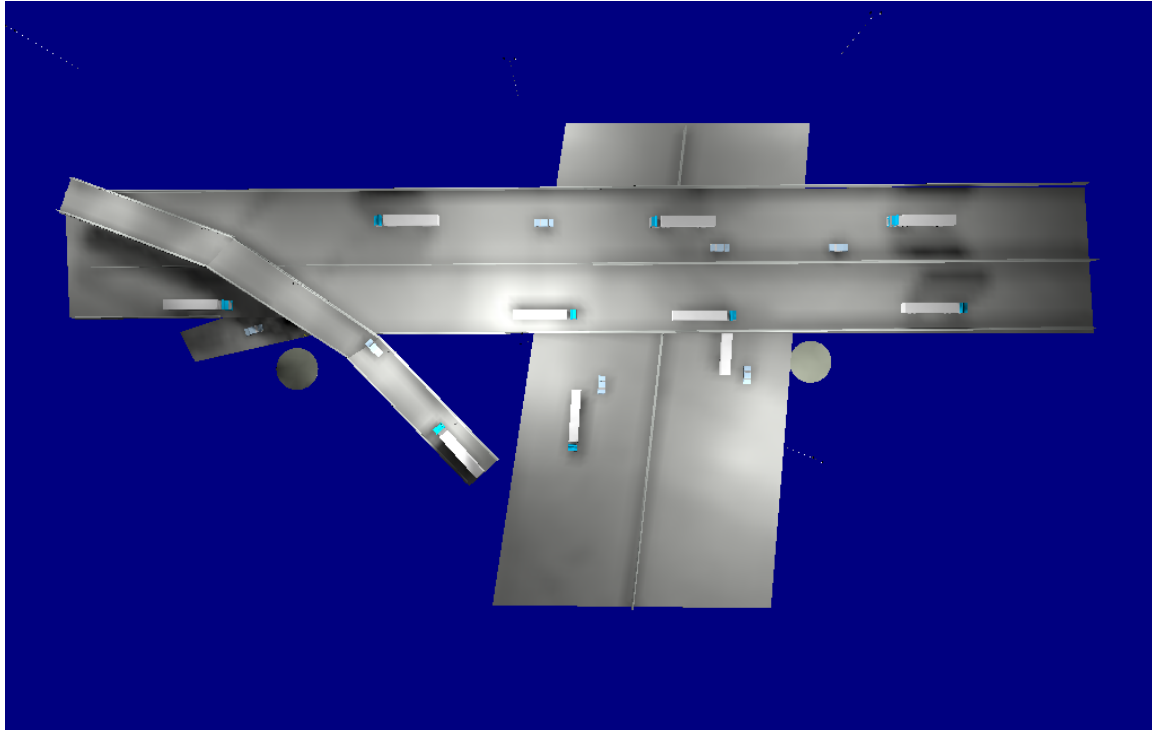


Figure 5-B
Rendering (The Solution)– Case Study

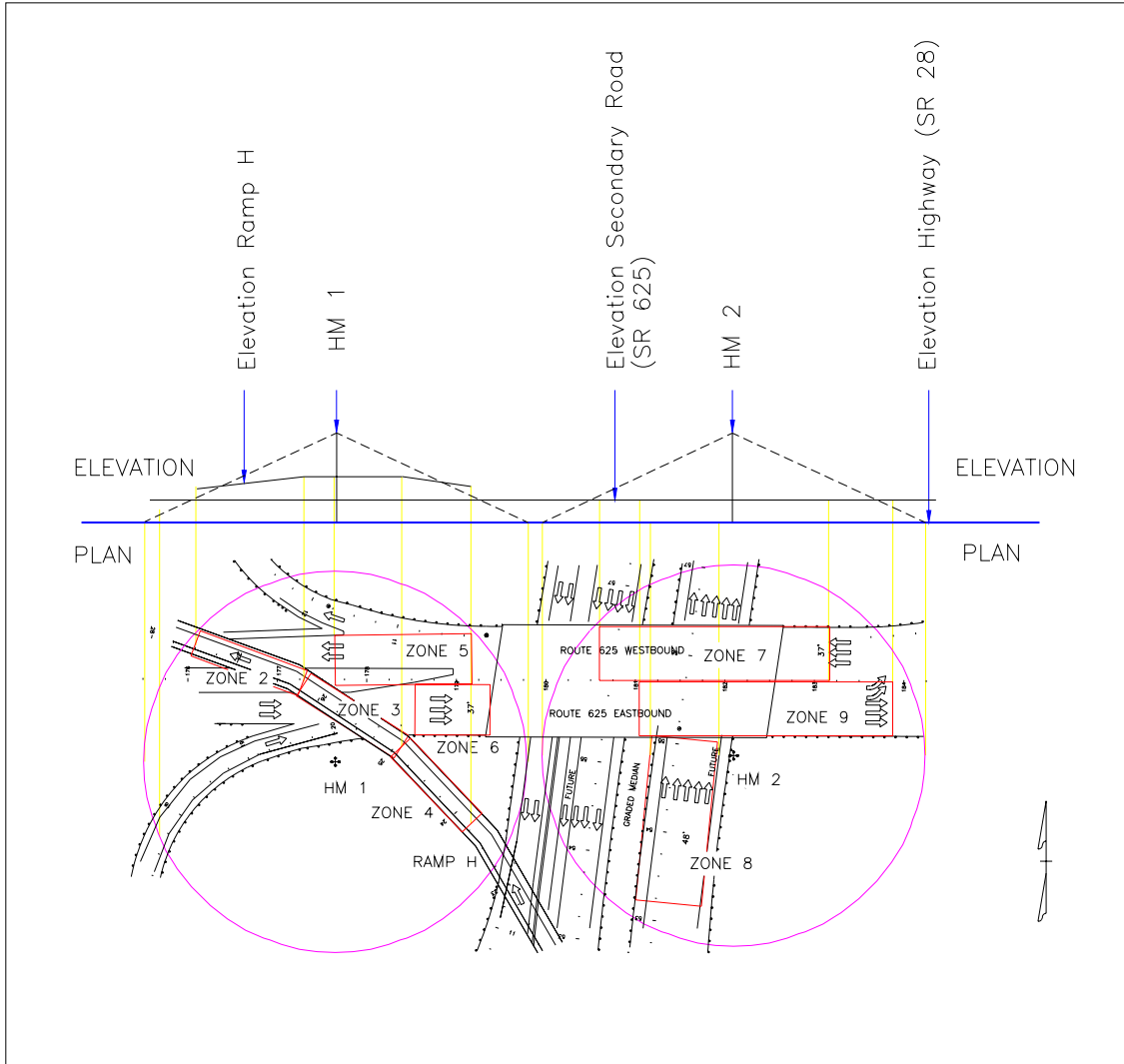


Figure 6
Plan and Elevation – Case Study

Table 2
Calculations - Case Study

	Criteria	Units	Avg	Max	Min	Avg/Min	Max/Min
Zone 2	Luminance	Cd/sq m	0.17	0.80	0.00	0.00	0.00
	Illuminance	fc	0.33	1.80	0.00	0.00	0.00
	Veiling Luminance	Cd/sq m	0.00	0.03	0.00	0.00	0.00
Zone 3	Luminance	Cd/sq m	0.23	0.30	0.20	1.15	1.50
	Illuminance	fc	0.70	0.70	0.70	1.00	1.00
	Veiling Luminance	Cd/sq m	0.02	0.06	0.00	0.00	0.00
Zone 4	Luminance	Cd/sq m	--	--	--	--	--
	Illuminance	fc	0.78	2.60	0.10	7.80	26.00
	Veiling Luminance	Cd/sq m	0.00	0.00	0.00	0.00	0.00
Zone 5	Luminance	Cd/sq m	0.28	0.50	0.00	0.00	0.00
	Illuminance	fc	0.62	1.30	0.10	6.20	13.00
	Veiling Luminance	Cd/sq m	0.00	0.00	0.00	0.00	0.00
Zone 6	Luminance	Cd/sq m	0.28	0.50	0.10	2.80	5.00
	Illuminance	fc	0.67	1.30	0.10	6.70	13.00
	Veiling Luminance	Cd/sq m	0.07	0.16	0.02	3.50	8.00
Zone 7	Luminance	Cd/sq m	0.30	0.60			
	Illuminance	fc	0.73	1.30	0.10	7.30	13.00
	Veiling Luminance	Cd/sq m	0.00	0.04	0.00	0.00	0.00
Zone 8	Luminance	Cd/sq m	0.44	1.20	0.10	4.40	12.00
	Illuminance	fc	0.65	0.70	0.30	2.17	2.33
	Veiling Luminance	Cd/sq m	0.00	0.03	0.00	0.00	0.00
Zone 9	Luminance	Cd/sq m	0.46	1.80	0.10	4.60	18.00
	Illuminance	fc	1.04	1.30	0.10	10.40	13.00
	Veiling Luminance	Cd/sq m	0.03	0.17	0.00	0.00	0.00

Locating the Fixtures and the Poles

Modern lighting design software will allow you to import the CAD files of the roadway. The CAD files typically contain more information than you need. For simplicity (and faster processing), activate only the layers you need for your work such as the edge of pavement, shoulder of the road, stationing, structures, curbs, sidewalks, etc. Eliminate the layers you don't need. You can combine the layers into one layer. Pay attention to the scales used in the files (hopefully they are at full scale) and the units.

The photometric characteristics of a fixture are available as an electronic file that presents the results of tests conducted by the manufacturers. A common type of file is the IES file. Usually a test number identifies the IES file. These test results are based on testing of a fixture with a specific lamp. Results may differ greatly if, say, a 400-watt lamp is replaced with a 250-watt lamp, even if the fixture is available with the smaller lamp. Performance is not necessarily scalable.

Most probably the software will allow you to select the fixture by selecting the IES file.

Iso-footcandle templates are an easy way to locate the fixtures (Remember you have already calculated the spacing during modeling of the sample areas of the roadway, use the spacing as an initial guidance for locating the fixtures). This method is not much different from what was done manually before software became available, but software makes it easier. There are many ways to use templates, but I have found out that, if you use a template with the minimum required illuminance for the road or a template with the average required illuminance, you will be able to better manipulate the location of the fixtures.

Play with the templates to get an idea of the influence of various design parameters on the lighting performance. Locate a few fixtures at a suitable distance from the edge of the pavement, or over the roadway if you are using arms. Place templates using various degrees of overlap and perform the pertinent lighting calculations.

In selecting the poles locations, make sure that you stay out of the clear zone of the roadway, behind manmade or natural deflectors. Install the poles behind the shoulder of the road. Stay away from signs and traffic signal lights. Also consider the hazard of servicing the poles. If you decided to put poles in the median make sure that the median is large enough to install the poles, and the shoulders are large enough to accommodate a maintenance truck.

Verifying the Lighting Design Criteria

Most designers now use commercially available software to model the lighting design, to locate the fixtures and perform lighting calculations. Point-by-point calculations produced using the software permits a level of design and analysis that was, until recently, not practical.

There are usually three criteria considered in roadway lighting: Luminance, Illuminance, and Small Target visibility.

- Luminance, in Candela/meter² (Cd/sq m) is a measure of how bright the roadway is, taking into consideration the amount of light reflected from the pavement.
- Illuminance, in Lux, is a measure of the amount of light incident on the roadway.
(In the United States footcandle is usually used as the unit for illuminance)

- Small target visibility is affected by factors such as the luminance of the target, the luminance of the immediate background, the adaptation level of the adjacent surroundings, and the disability glare. Small target visibility is a weighted average.

These criteria are typically computed for a discrete area (zone) of interest. Of more interest that specific values are the minimum, maximum, and average values within the zone and the ratios of average-to-minimum and maximum-to-minimum. The calculated values should be within the recommended design criterion.

As a rule-of-thumb, you can increase the average illuminance level by locating the fixtures closer together. In other words, the average illuminance will increase as the iso-footcandle templates overlap more. Alternately, you can use higher wattage lamps (higher Lumens) - you have to check first with the manufacturers to verify that you can do that.

Often you can meet the required average level of illumination but the minimum level of lighting is well below the requirement. You have to look at the area you selected to conduct the calculations. Select an area that traces the edge of the pavement, and covered with templates.

Notice that the average-to-minimum illumination ratio is important, and if the minimum illumination is low, then the average to minimum illumination ratio will be high. You can take one of these measures in order to increase the minimum, and improve the average to minimum ratio: add another fixture, aim or reorient a fixture or several fixtures toward the point of minimum illumination level.

Sometimes an area receives more light than the rest of the calculations zone. This might happen due to a concentration of fixtures or due to spillover from fixtures outside of the calculation zone. Make sure that you identify the point or points of maximum illumination, and try to eliminate the reason for this level of higher illumination. You might relocate, remove, or reorient fixtures.

Table B1 of the RP-8-00 shows valuable relationships between the different factors.

LIGHTING POLLUTION

An important issue that the roadway lighting designer must be concerned with is lighting pollution caused by glare, light trespass and “urban sky glow”. Lighting pollution has become a significant political issue. It has been found that 35-to-50 percent of lighting pollution in the U.S. is caused by roadway lighting. This means that the solution to a significant part of the problem is in the hands of the lighting designer.

Glare

There are several types of glare; the one that we are most concerned with is disability glare - glare that causes reduced visual performance. Disability glare, or “veiling luminance” as we will refer to it, reduces the ability of the driver to distinguish objects clearly.

The veiling luminance, L_v , can be calculated as:

$$L_v = \Sigma 10 E_{vi} / (\theta^2 + 1.5 \theta)$$

Where:

- L_v : Veiling Luminance, at the observer location, in Candela/meter².
- E_v : Vertical illuminance, on the plane of the observer's eye.
- θ : Angle between the line of sight and luminaries, in degrees.
- N : Number of luminaries in sight.

Notice that θ depends on the fixture mounting height and other factors like the width of the road, the height of the observer's eyes, and the observer's location. Also notice that there is a contribution in the value of the glare due to the other fixtures that the observer can see.

This simply means that we can reduce the value of the Veiling Luminance by decreasing the vertical illuminance and increasing the angle θ . This can be achieved by:

1. Selecting luminaries of low vertical illuminance. (Remember we still have to meet the criteria)
2. Increase the mounting height.
3. Increase the spacing between poles.

Something to consider is that increasing the mounting height may result in a considerable price increase to the project. Increasing fixtures spacing will generally result in a less costly design.

Light Trespass

Be aware that when you illuminate a roadway you are also illuminating the area around the pole. Light may fall in places where it is not wanted such as residential areas, annoying people and possibly depriving them of sleep. It might interfere with the performance of security cameras.

An acceptable level of light trespass is typically 0.01-footcandle, which is equivalent to moon light. An easy way to find the limit of trespass is to utilize a fixture template that has an iso-footcandle of 0.01. When you have plotted the fixture locations draw a tangent to the 0.01 iso-footcandle, this line will define the limit of the light trespass.

Avoid using high masts fixtures close to residential areas, hospitals and hotels, and Airports unless FAA approval is obtained.

Urban Sky Glow

It is the right of our children and future generations to look up and see the stars. Lighting above 90 degrees participates in the urban sky glow. Use cut off luminaries and luminaries with shields around them to help solve the problem.

Confusion

The worst thing any designer would like to have happen is that a driver could be confused due to the roadway lighting. Make sure that intersections, converging traffic points, diverging traffic points, ramps and islands are well lit. Notice that at intersections, points of diverging and converging traffic, ramps, etc., the width of the roadway, as well as the geometry change. Use poles with 2, 3, or 4 fixtures. Also reduce the spacing to provide these critical areas with good lighting.

A roadway parallel to or close to an airport runway can create a disaster. Avoid this situation, and use shields on the fixtures to control light spill and patterns of poles locations that differ from the ones on a runway.

A tired driver can take the wrong exit, miss it all together, or get into an accident due to being confused by lighting patterns. Avoid this situation, know where the signs are, and make sure that they are well seen. Consider the lighting patterns at the exits, the entrances, the channeled roadways and the medians. Ensure they are well lit and that the patterns will not cause confusion.

OTHER IMPORTANT ISSUES

Energy Consumption

Another factor the designer has to be concerned with is the energy consumption. Although the energy consumption price does not appear on the bill of material, it is a cost that the customer will have to pay (as a matter of fact, the whole community has to pay). Select high efficiency luminaries, ballasts and transformers. Consider low level lighting using 100 Watt, and 150 Watt lamps on narrower roads and ramps, and higher level lighting using 400 Watt, and high masts on larger roads. Calculate the energy consumption for the design. Consider alternate design strategies that could lower energy consumption.

Aesthetics

Use your common sense in selecting the fixtures and the poles. If the project is an extension of a roadway try to match the fixtures and the poles. Use attractive fixtures and poles in residential area, without sacrificing the photometric performance or the maintenance criteria. Select appropriate fixtures and poles in historical or down town areas. Lighting can influence people – hopefully for the better.

Tunnel Lighting

Lighting a tunnel at night is not much different than lighting an open roadway; however, lighting the tunnel during the day is a problem that deserves good attention. The tunnel itself is a hazard. It can appear during the day as a black hole that prompt the driver to suddenly slow down, which could be a factor in causing an accident.

The problem is also a problem of adaptability. Human eyes can adapt easiest moving from higher levels of illumination to lower levels of illumination. The transition from daylight (about 10,000 foot-candles) into darkness can blind the driver momentarily. It is recommended that very high lighting levels (1000-1,500 footcandle dropping down to 800 footcandles) at the entrance of the tunnel and for a short distance of about 10 percent of the length of the tunnel. The illumination level should then be decreased to about 50 footcandle for about another 20 percent of the length of the tunnel. This scheme is reversed on the other side of the tunnel. The central portion of the tunnel (about 40 percent of the tunnel length) can be lit from 20 footcandle to 5 footcandle.

The daylight illumination will change from one day to another, season to season. You might consider an automated system that will vary the illuminance level, based on the intensity of the daylight. Consider an intermediate light level for dawn and dusk.

Select watertight luminaries using low pressure sodium lamps with features such as ease of maintenance and installation. Also consider fixtures with thin profiles to minimize the risks due to small clearances.

Underbridge Lighting

You can think of the area under a bridge as a short tunnel; however the problem of adaptation is not as severe. We recommend continuously lighting the underbridge area. Also use non-cutoff, high pressure sodium fixtures. The non-cutoff fixtures will light the underside of the deck, reducing the cavern effect.

CONCLUSION:

Roadway lighting design is a responsibility that should be taken seriously – the safety of the public is impacted by design decisions. A designer should apply a logical and systematic approach, asking questions such as “What is the basis for selecting this fixture?”, “What is the basis for using this spacing?”, “Why will I use this mounting height?”. In other words, the designer should move from the realm of art only to the realm of science and common sense. A designer should always remember that the ultimate purpose of Roadway Lighting Design is safety.