Roadway Unit Uplight Density (UUD) Calculation Examples

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The following examples of calculations were developed from research by Marshall Design, Inc. into roadway lighting design, as discussed in the paper *"Roadway Lighting Design for Optimization of UPD, STV and Uplight"*, Journal of the IES, Summer 2000 (v29n2), with some modifications. The modifications have to do with using the average Light Loss Factor, as discussed below. These examples were developed for a PowerPoint presentation to the 2001 IESNA Street and Area Lighting Conference, which is available for download at "http://resodance.com/mdi/SALC2001.html". Details about the lighting systems' data, procedures and calculations are available in that presentation. This report and the referenced photometric files are available at "http://resodance.com/mdi/SALC_exs.html".

The roadway lighting systems were calculated using custom optimization software to meet the criteria for both the illuminance and luminance methods of the current ANSI/IESNA *American National Standard Practice for Roadway Lighting*, RP-8-00. The systems using 400W metal halide lamps for 13 meter wide (4 lane) roadways were ranked by Unit Power Density (UPD).

The Unit Power Density (UPD) was calculated as the number of luminaires per cycle times the input Watts per luminaire divided by the roadway area, defined as the luminaire cycle distance times the number of lanes time the width of the lanes. The number of luminaires per cycle is two for stagger layouts. The input Watts was increased by 15%, to be consistent with the IESNA *Unit Power Density (UPD) for New Roadway Lighting Installations*, LEM-6-87. The resulting value, when lengths are measured in meters, has units of Watts/sq. meter of roadway.

Eq 1: UPD = #Lum * Watts/Lum / (Spacing * #Lanes * Width)

The list of the systems with the seven lowest values is shown in Table 1. Note that the illuminance Eavg are maintained values, for comparison with the criteria of RP-8-00. A review of the photometric files showed that, of the seven files with the lowest UPD values, only Samp0477 had incomplete upper hemisphere photometry, and therefore that file was not suitable for uplight calculations. The other files represent a range of cutoff classifications, with two each of full cutoff, cutoff and non-cutoff.

Table 1: UPD Ranking of 400W Metal Halide Systems for 13m Wide Major Roadway

IESFile	Cutoff	UPD W/m2	LumCycle m	Eavg lx	RtdLms lumens
Samp0191	CO	0.73	111	13.0	44000
Samp0479	NC	0.73	111	13.1	44000
Samp0195	CO	0.74	109	13.0	44000
~~Samp0477~~	~~CO~~	~~0.74~~	~~109~~	~~13.0~~	~~44000~~
Samp0478	NC	0.74	109	13.3	44000
Samp0187	FC	0.78	103	13.0	44000
Samp0209	FC	0.78	103	13.1	44000

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The distribution of initial lumens from each file is shown in Table 2. The lumen values shown are initial, and the average Light Loss Factor (as discussed below) is also shown.

Table 2: Distribution of Initial Lumens and Average Light Loss Factor

IESFile	Cutoff	RtdLms lumens	LumsDn lumens	LumsUp lumens	LLFavg
Samp0191	CO	44,000	32,675	1,160	0.75
Samp0479	NC	44,000	32,461	2	0.75
Samp0195	CO	44,000	31,822	313	0.75
Samp0478	NC	44,000	32,302	0	0.75
Samp0187	FC	44,000	29,632	0	0.75
Samp0209	FC	44,000	35,063	0	0.75

The Unit Uplight Density (UUD) was calculated as the sum of direct uplight and reflected downlight divided by the roadway area. The downward lumens "LumsDn" and the upward lumens "LumsUp" were calculated from the photometric file and adjusted for any difference between the rated lumens of the photometry and the lamp lumens in the roadway calculation and for the average Light Loss Factor (LLF). The average LLF (LLFavg) is taken as the average of the maintained LLF and 1.0, and applied to the upward and downward lumens and also to adjust the illuminance onto the roadway from the maintained value to the average value. The reflected light was calculated as the sum of the roadway reflected light and the off-roadway reflected light. The roadway reflected light was calculated as the roadway reflectance times the roadway lumens, which was calculated as the average illuminance value times the roadway area. The off-roadway reflected light was calculated as the off-roadway reflectance times the off-roadway lumens, equal to the total downlight lumens minus the roadway lumens. The total downlight lumens was calculated as the number of luminaires per cycle times the downlight lumens per luminaire. The resulting value, when lengths are measured in meters, has units of lumens per square meter of roadway.

Eq. 2: UUD = [(#Lum * UpwardLums) + (rhoRoad * Eavg * Area) + (rhoOffRoad * {#Lum * DnwardLums - Eavg * Area})] / [Area]

Roadway reflectance (rhoRoad) was set at 0.07, the default Qo value for R3 pavement (per RP-8-00), which is the roadway surface used throughout these calculations. Off-roadway reflectance (rhoOffRoad) was set to 0.18, the "Kodak average reflectance value". For these examples, all the roadways are 13m wide, so the Area is 13 meters times the LumCycle distance shown in Table 1. All the roadways have staggered layouts, so two luminaires are used when calculating lumens within each luminaire cycle. The maintained LLF used in the optimization calculations is 0.50, so the average LLF (LLFavg) is 0.75 for all systems. The UUD values are all calculated using the average LLF, because typical roadway conditions - over both space and time - are midway between initial and maintained, so uplight calculations should be made at that level of maintenance.

Table 3 shows a summary of the uplight calculation values and the UUD values, in lumens per square meter of roadway.

Table 3: UUD Calculations' Intermediate Values and Results

IESFile	Cutoff	EavgAvg lx	OntoRd lumens	Dnward lumens	OffRoad lumens	Upward lumens	TotalUp lumens	UUD lum/m2
Samp0191	CO	19.50	28,139	49,013	20,874	1,740	7,467	5.2
Samp0479	NC	19.65	28,355	48,692	20,337	3	5,648	3.9
Samp0195	CO	19.50	27,632	47,733	20,102	470	6,022	4.2
Samp0478	NC	19.95	28,269	48,453	20,184	0	5,612	4.0
Samp0187	FC	19.50	26,111	44,448	18,338	0	5,128	3.8
Samp0209	FC	19.65	26,311	52,595	26,283	0	6,573	4.9

The calculation procedure, using LLFavg as discussed above, is as follows.

The Eavg-maintained, which is shown in Table 1, is divided by the maintained LLF (0.50 for all systems in these examples) to get Eavg-initial and then multiplied by the LLFavg to get "EavgAvg". This value is multiplied by the Area of the roadway (equal to 13m width times the LumCycle distance in Table 1) to get the "OntoRd" lumens. These are the lumens which fall onto the roadway surface over the entire luminaire cycle, when the average LLF applies.

The "Dnward" lumens are calculated from the values in Table 2 by multiplying them by 2, because there are two luminaires in each staggered cycle, and then by the LLFavg, to get the lumens which are directed downward. The "OffRoad" lumens values are calculated as the "Dnward" lumens minus the "OntoRd" lumens.

The "Upward" lumens are calculated from the values in Table 2 by multiplying them by 2, because there are two luminaires in each staggered cycle, and then by the LLFavg, to get the lumens which are directed upward.

The "TotalUp" values are calculated by adding three values together. The first is the uplight from the roadway, equal to the roadway reflectance of 0.07 times the "OntoRd" lumens. The second is the uplight from the off-roadway area, equal to the off-roadway reflectance of 0.18 times the "OffRoad" lumens. The third is the direct uplight from the luminaires, equal to the "Upward" lumens.

The UUD is equal to the "TotalUp" lumens divided by the Area, which is the LumCycle from Table 1 times 13m. The UUD values are in the units of lumens per square meter of roadway, and specific to the particular combinations of luminaire, lighting system and roadway.

From inspection of the values in Table 3, it is evident that the cutoff classification does not in any way predict the uplight from the luminaires or the lighting system.