Effect of Street Lighting on Bats

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02/01/2008

This paper looks at the effect street lighting has on bats and evaluates the effectiveness of various methods of controlling light spill onto surrounding areas.
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Introduction

The ever increasing pressure on the countryside due to development inevitably has an impact on wildlife. For safety, security and amenity, new developments are usually accompanied by street lighting. Whilst generally this has a positive effect for the human population, nocturnal species can find this sufficiently distressing that their existence is threatened. Probably one of the most sensitive creatures in this respect are bats. For example, bats leave their roosts at night and follow a regular “commuting” route to feeding areas. If this route is affected by artificial lighting they can abandon it with potentially catastrophic consequences on their ability to feed. Finding alternative routes or feeding grounds is not necessarily a given and measures must be taken to remove the threat by designing the lighting scheme appropriately. Careful design and selection of luminaires and lighting schemes makes this perfectly possible with a satisfactory outcome for both species of residents.

Theory

Bats are a nocturnal species and the exact reason why they avoid light and flying during daylight hours is actually unknown. The theory that has generally been accepted is that it is a predator avoidance mechanism. What has been proven through years of study is that all but 3 of the UK’s 17 different bat species will not fly in directly illuminated areas. This means that directly illuminating a bat roost or even a known feeding route could result in an offence being committed as the bats are a protected species under the Wildlife & Countryside Act (1981), stating that it is illegal to kill, injure, capture or even disturb bats.

The reason that the light can be classed as a disturbance to bats is that by avoiding light, bats will not emerge from the roost when the nocturnal insects that they feed on are in abundance. This is generally around dusk and dawn times, so if there are any delays in the bats emerging from the roost they would lose out on vital feeding time. Studies have shown that illuminance levels as low as 0.06 lux can have an effect on the behaviour of bats. It has been known that on some occasions bats will not fly on nights when there is a full moon, as this is typically 0.2 lux. This means that in most cases where there is a population of bats there should be negligible light spill on to the affected area.

There are also a variety of classes of light source available each emitting light at various wavelengths and intensities and each of these affect the bats in different ways. The main types of light source used in street lighting are;

- **Low Pressure Sodium (SOX)** – these lamps emit light at a single wavelength with a very low amount of UV meaning that very few insects are attracted to this light source. This light also has a minimal effect on the bats.

- **High Pressure Sodium (SON)** – these lamps emit light over a slightly broader wavelength spectrum attracting more insects but as these are a more intense light source they have a greater effect on bats.

- **Metal Halide** – There are a range of metal halide lamps available and they are classed as white light sources, these emit light at wavelengths across the colour spectrum but can also emit high levels of UV. These can attract large numbers of insects and are also a closer match daylight meaning these have an even greater impact on bats.
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Table 1 shows a summary of technical data for the lamps.

<table>
<thead>
<tr>
<th>Lamp Type</th>
<th>W from to</th>
<th>lm/W +/-</th>
<th>Life +/- h</th>
<th>T°</th>
<th>Ra</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Halide</td>
<td>35-150</td>
<td>85-8,000</td>
<td>4000K 85</td>
<td>Small</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low Pres. Sod.</td>
<td>18-180</td>
<td>200-15,000</td>
<td>1800K 0</td>
<td>Long</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Press. Sod.</td>
<td>50-1,000</td>
<td>120-16,000</td>
<td>2000K 25</td>
<td>Mid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The SOX lamps are generally very large, typically 750-1000mm in length for a 135W lamp. This makes the luminaires housing them very large and the light emitted hard to control resulting in large amounts of light spill away from the area being lit (the task area). These lamps were popular due to the high lamp efficacy, typically 175-200 lm/W. High Pressure Sodium lamps are much more compact, typically 200-250mm for a 150W lamp, and although the lamp efficacy is lower, typically 120-150 lm/W, the light is much more easily controlled by a reflector resulting in a higher overall efficiency than the SOX system and, critically, the light spill can be reduced. The SOX lamps are slowly being phased out as and replaced by the SON. The metal halide lamps are also compact making the light easier to control, however the output of the lamp and lamp life compared to the Sodium lamps is lower.

There are a large variety of street lighting luminaires available, each with their own range of optical compartments designed to distribute light in a different way. This is because lighting applications can vary from narrow single carriageway roads that are only 6m wide, to 4 lane motorways that are 20m plus across. Each optic is designed to ensure that as much of the light emitted as possible goes where it is required. However as the lighting requirements for each of these roads is different and the minimum lighting levels vary, the amount of light spilling away from the road also varies.

The general principles used for the reduction of light spill in street lighting is to reduce the light emitted from the luminaires at angles greater than 70° from the vertical plane, light at these angles, especially to the front and rear of the luminaire, is unlikely to reach the target area and will be wasted spilling out on to the surrounding areas. To meet this requirement a luminaire utilising a flat glass protector is often specified. Also by ensuring that the columns are kept as low as possible the light source is closer to the target area reducing the area that the light can cover. However, this would be a compromise as the columns would have to be high enough to ensure that light can be emitted at lower angles can still provide adequate illumination over the target area.

Where the control of light spill is required to be more than the above principles can achieve, then there are further options involving accessories that can be considered;

- **Shields** – these can be mounted at the front or back of the luminaire. Figure 1 shows a typical rear shield accessory.
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Figure 1

• *Masking* – by painting a section of the luminaires protector, light will be blocked from going through. Figure 2 shows a luminaire with a section of the protector masked off.

Figure 2

• *Louvres* – these can be either internal or external. They are rows of slates angled to block the light in a certain direction. Figure 3 below shows a typical front and rear internal louvres.

Figure 3
Effect of Street Lighting on Bats

Analysis

To investigate each of the most common methods of controlling light spill in detail, each option has been compared by calculating the lighting levels for the task area and showing the light spill at 1 lux, 5 lux & 10 lux onto the surrounding area. The extent of the light spill directly behind the column has been measured. The photometry available at this time is limited, so the calculations have been carried out in situations where the luminaire with the available photometry is best suited. The lighting levels have been measured with and without the accessory to give the percentage decrease in the amount of light spill. This gives a fair comparison between the available options for conclusions to be drawn. All the calculations have been carried out using SON lamps as they are the most widely used light source in street lighting applications.

Using Flat Glass Protectors

The majority of Traffic Route luminaires are available with a flat glass protector option, so this method of limiting light emitted at high angles is easily available at little or no extra cost on unit prices. However the range of protectors typically used on traffic route lighting include curved bowls due to their less restrictive light distribution, so a comparison has been made between a flat glass protector and a curved glass protector. All other variables, such as reflector type, light source & power, and mounting height were left constant.

Road Details – Single Carriageway, 3.65m lane width, 1.5m column setback, single sided arrangement, lit to BS5489-1:2003 lighting class ME3a.

See Appendix A for the Lighting calculations with a summary of the luminaires used. Figures 4 & 5 below show the isolux plots of 1, 5 & 10 lux with luminaires positioned at their maximum allowable spacing as determined by the calculations in Appendix A.
Effect of Street Lighting on Bats

Table 2 below summaries the results of the calculations;

<table>
<thead>
<tr>
<th></th>
<th>Column Spacing</th>
<th>Unit Costs</th>
<th>Dist to 1 Lux</th>
<th>Dist to 5 Lux</th>
<th>Dist to 10 Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curved Protector</td>
<td>42m</td>
<td>325</td>
<td>15m</td>
<td>8.5m</td>
<td>5.3m</td>
</tr>
<tr>
<td>Flat Protector</td>
<td>39m</td>
<td>325</td>
<td>15m</td>
<td>8.2m</td>
<td>5.1m</td>
</tr>
<tr>
<td>% - Change</td>
<td>7.1</td>
<td>0</td>
<td>0</td>
<td>3.5</td>
<td>3.7</td>
</tr>
</tbody>
</table>

Table 2

The results show that there is little effect on the spread of light when a flat protector is used to light this road. This is due to the decreased column spacing required to still achieve the required lighting specification on the road increasing the intensity of the light in the area. The decrease in column spacing will also mean that extra columns could be required on longer stretches of road increasing costs.

Lower Mounting Height

This option is easily implemented and would generally result in a reduced column cost. This calculation compares 8m and 10m columns. The calculation compares the same luminaire and light source mounted at the 2 different heights.

Road Details – Single Carriageway, 3.65m lane width, 1.5m column setback, single sided arrangement, lit to BS5489-1:2003 lighting class ME3a.

See Appendix A for the Lighting calculations with a summary of the luminaires used. Figures 6 & 7 below show the isolux plots of 1, 5 & 10 lux with luminaires positioned at their maximum allowable spacing as determined by the calculations in Appendix A.

Figure 6 - Light Spread with 10m Columns
Table 3 below summaries the results of the calculations;

<table>
<thead>
<tr>
<th>Column Spacing</th>
<th>Unit Costs</th>
<th>Dist to 1 Lux</th>
<th>Dist to 5 Lux</th>
<th>Dist to 10 Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>10m Column</td>
<td>39m</td>
<td>325</td>
<td>15m</td>
<td>8.2m</td>
</tr>
<tr>
<td>8m Column</td>
<td>31m</td>
<td>225</td>
<td>13.1m</td>
<td>7.6m</td>
</tr>
<tr>
<td>% - Change</td>
<td>20.5</td>
<td>30.8</td>
<td>12.6</td>
<td>7.3</td>
</tr>
</tbody>
</table>

The overall spread of light has been reduced by lowering the column height, however due to the lower mounting height the intensity of the light on the road has been increased with the higher illuminance values spreading further. This option reduces the column spacing by 20% resulting in more columns being required thereby neutralising the benefit of the lower unit costs.

**Rear Shield**

Shields are becoming more widely available on a range of luminaires but as they are an accessory they incur an extra cost per luminaire. The longer the length of the shield the more effective it is, however the increased surface area causes greater stresses on the supporting column and bracket due to wind loading.

Road Details – Single Carriageway, 3.65m lane width, 1.5m column setback, single sided arrangement, lit to BS5489-1:2003 lighting class ME3a.

See Appendix A for the Lighting calculations with a summary of the luminaires used. For the shielded unit, a 120mm rear mounted shield has been applied. Figures 8 & 9 below show the isolux plots of 1, 5 & 10 lux with luminaires positioned at their maximum allowable spacing as determined by the calculations in Appendix A.
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Table 4 below summaries the results of the calculations;

<table>
<thead>
<tr>
<th>Column Spacing</th>
<th>Unit Costs</th>
<th>Dist to 1 Lux</th>
<th>Dist to 5 Lux</th>
<th>Dist to 10 Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unshielded</td>
<td>44m</td>
<td>325</td>
<td>15.3m</td>
<td>8m</td>
</tr>
<tr>
<td>120mm Rear Shield</td>
<td>35m</td>
<td>340</td>
<td>9.2m</td>
<td>6.6m</td>
</tr>
<tr>
<td>% - Change</td>
<td>20.5</td>
<td>4.4</td>
<td>39.9</td>
<td>17.5</td>
</tr>
</tbody>
</table>

The shield has helped reduced the spread of light behind the lighting column by almost 40%. However, the column spacing is reduced by 20% resulting in the possibility of more columns being required and also there is an increased unit cost for the accessory.

Masking

Masking can only be done on polycarbonate luminaires which restricts the power of the light source as there are lower thermal limits on these units. This also rules out flat protectors for the same reason, meaning that a deeper bowl is used resulting in increased upward light spill from the units. Any amount of the protector can be masked, but as it is an additional process in the manufacture of the units additional costs incur.

Unfortunately there is currently no photometry available for luminaires with sections of the protector being masked so a comparison calculation for the lighting levels is not possible. However Figure 9 below shows a cross section view of a typical unit with the projected lines of light spread to give an estimate. The projection of 1 lux has been measured from an unmasked unit.
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The masking reduces the projection of light to 3m behind the base of the column, a reduction of 71%. The effect on the lighting levels on the road is unknown.

Louvres - Internal
As with masking, the internal louvres are not available with a flat protector due to the limited space available inside the optic. Louvres are a specially designed accessory with each one requiring testing resulting in higher additional costs per unit than any of the previous options.

Road Details – Single Carriageway, 5.5m overall Carriageway with 2m Footpath each side and columns at rear of footpath, lit to BS5489-1:2003 lighting class S3.

See Appendix A for the Lighting calculations with a summary of the luminaires used. As the photometry available is only for a unit typically used in residential applications the comparison has been made here. Figures 11 & 12 below show the isolux plots of 1, 5 & 10 lux with luminaires positioned at their maximum allowable spacing as determined by the calculations in Appendix A.
Table 5 below summaries the results of the calculations:

<table>
<thead>
<tr>
<th>Column Spacing</th>
<th>Unit Costs</th>
<th>Dist to 1 Lux</th>
<th>Dist to 5 Lux</th>
<th>Dist to 10 Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unlouvred</td>
<td>38m</td>
<td>220</td>
<td>9.5m</td>
<td>5.4m</td>
</tr>
<tr>
<td>Internal Rear Louvre</td>
<td>29m</td>
<td>250</td>
<td>3m</td>
<td>0.9m</td>
</tr>
<tr>
<td>% - Change</td>
<td>23.7</td>
<td>12</td>
<td>68.4</td>
<td>83.3</td>
</tr>
</tbody>
</table>

The internal rear louvre greatly reduces the spread of light behind the units. However it does reduce the column spacing achievable, this is because the louvre is blocking the light emitted from the optic making the luminaire less efficient.

Louvres – External

External louvres are used with a flat protector so there is no spacing constraint from the optic. As with the shields these are externally mounted so there are increased stresses on the supporting columns and brackets from additional wind loading. As with the internal louvres an additional unit cost will incur.

Road Details – Single Carriageway, 3.65m lane width, 1.5m column setback, single sided arrangement, lit to BS5489-1:2003 lighting class ME3a.

See Appendix A for the Lighting calculations with a summary of the luminaires used. Figures 13 & 14 below show the isolux plots of 1, 5 & 10 lux with luminaires positioned at their maximum allowable spacing as determined by the calculations in Appendix A.
Table 6 below summaries the results of the calculations:

<table>
<thead>
<tr>
<th></th>
<th>Column Spacing</th>
<th>Unit Costs</th>
<th>Dist to 1 Lux</th>
<th>Dist to 5 Lux</th>
<th>Dist to 10 Lux</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unlouvred</td>
<td>34m</td>
<td>325</td>
<td>15.3m</td>
<td>7m</td>
<td>3.6m</td>
</tr>
<tr>
<td>External Rear Louvre</td>
<td>20m</td>
<td>355</td>
<td>0.4m</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>% - Change</td>
<td>41.2</td>
<td>8.5</td>
<td>97.3</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

The external louvre almost completely blocks all the light emitted behind the units. However, this does have a greater effect on the column spacing achievable as large amounts of light are being blocked.

**Case Study – Enterprise Way, Sirhowy**

The Enterprise Way project in Sirhowy, South Wales included road improvements to the A4048 and A472, 2 strategic routes in Wales. These improvements along with new link roads and bridges were required to ensure the Oakdale Business Park achieved its full potential. This is a large new business park creating around 12,000 jobs on the site. During the planning phase of the project extensive environmental studies were carried out in the area to enable the route to be planned with minimum effect on the environment. However some disruption was inevitable and measures were taken to ensure that this was kept to a minimum.

Due to the unavoidable close proximity of the road to the bat’s roosting and commuting routes, the light pollution control from the street lights needed to be extremely tight to minimise disruption to the valley’s bat population. In this case utilising a luminaire with a flat protector was
not effective enough to meet the requirement of no more than 0.6 lux at a distance of 1.5m behind the lighting column. Investigations proved that shields attached to the luminaires were unable to sufficiently reduce the light spill to meet the requirements. The best option was to use a louvre to reduce the light spill. At the time only the internal louvre options existed and these weren’t suitable for the flat glass units that were being used on the scheme. After trialling a number of different louvre designs, Figure 15 shows the optimum design that was approved for the scheme.

Figure 15

This bespoke louvre could be fitted to the luminaires proposed for the site. The slats are designed to ensure that the light cannot go directly behind the luminaire and at an angle that will cause minimal interference to the necessary light going forward onto the target area. The sides of the louvre do however reduce the spread of light to the side of the luminaires, but this was a compromise required en to ensure that the road was given environmental approval.

Conclusions

To avoid contravening the Wildlife & Countryside Act (1981) we are required not to disturb bats. This could include directly illuminating either their roosts or the paths they follow to their feeding grounds as from past research we know that the majority of species of bat in this country avoid illuminated areas. Although there is no legal requirement to light public highways there are many benefits in doing so and if the decision is taken to light the road, there are standards that need to be met.

The modern design of optics and lamps used in street lighting has helped reduce the amount of light spill onto the surrounding area, however as little as 0.06 lux can cause a disturbance to bats so reducing light spill to levels as low as this is a difficult task. The results of the comparison calculations between the most common methods used to reduce light pollution has shown that in most cases even 1 lux will spread at least 10m from the lighting column in a typical road lighting situation without some type of intervention.

The results of the calculations show that the accessories available are beneficial and do have a positive effect in reducing light spill. The degree of that effect is dependent on the complexity of
the accessory. The basic shielding and masking techniques do have an effect and the calculations show that they can reduce the light spill by as much as 40%. However, both the internal and external louvres are much more effective with the external louvre reducing the light spill by as much as 97%. The external louvres are more effective than the internal louvres as the internal versions can only be applied to protectors with a shallow or deep profile resulting in light spilling at higher angles.

The disadvantages are that the louvres are a specialist accessory and will increase the luminaire cost by up to 12%. More importantly, by blocking the light coming out of the luminaire they reduce the efficiency of the units and therefore reduce the maximum column spacing achievable to still maintain the light levels on the road. This can be by as much as 41%, further increasing the cost of lighting a given stretch of road.

Due to the high costs of using the louvres these should only be applied in severe situations where the road is extremely close to the bats, otherwise shielding is a cheaper option and will have a lesser impact of the lighting levels on the road but can still reduce light spill by 40%.

This report has concentrated on the lighting in Bat sensitive areas, but there are other species that also avoid the light where these principles can be applied, as well as in residential areas to avoid light pollution on to private properties.
Appendix

Appendix 1 - Lighting Levels with 10m Sapphire using CTG Protector.

Project: Lighting for Bats - Comparison Calculations  File: ...\Training\Young Lighters\CTG Calc.pf

General information: Standard CEN

Road details

<table>
<thead>
<tr>
<th>Arrangement</th>
<th>Driving</th>
<th>Way</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

| No. of lanes: | 2 |
| Lane width:   | 3.650 m |
| Road width:   | 7.300 m |

| Calculation: | ✔ Luminance |
|             | ❏ Illuminance (Z Positive) |
|             | ❏ Hemi-sph. Ill. |
|             | ❏ Ti |
|             | ❏ Illuminance (Y Positive) |
|             | ❏ Semi-oct. Ill. |

Luminance details

| Spacing: | 42.000 m |
| Height:  | 10.600 m |
| Overhang: | 0.000 m |
| Setback: | -1.650 m |

| Inclination: | 0.0 |
| Type:        | Sapphire2 |
| Protector:   | CTG |
| M:           | 2623573X |
| Source:      | SON-T+ |
| Wattage:     | 150 W |
| Flux:        | 17.5 lm |
| MP:          | 0.87 |

Summary

<table>
<thead>
<tr>
<th>Luminance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>Obey</td>
</tr>
<tr>
<td>LAv</td>
</tr>
<tr>
<td>Up</td>
</tr>
<tr>
<td>Uv</td>
</tr>
<tr>
<td>Ti</td>
</tr>
</tbody>
</table>

Observer position: -23.275; 1.025; 1.602 m

Schema

![Diagram of lighting setup]
Effect of Street Lighting on Bats

Appendix 1 - Lighting Levels with 10m Sapphire using PS Protector.

Project: Lighting for Bats - Companion Calculations

General information: Standard CEN

Road details

Arrangement: 2
No. of lanes: 2
Lane width: 3.650 m
Road width: 7.000 m

Calculation: Luminance
Calculation details:
- Spacing: 3.950 m
- Height: 10.000 m
- Overhang: 0.000 m
- Setback: 0.000 m
- Inclination: 0°

Type: Sapphire 2
Protector: Flat Glass
Reflector: 1963
Source: SON-T+2
Wattage: 150 W
Flux: 17.5 km
NF: 0.87

Summary

Luminance

<table>
<thead>
<tr>
<th>OBEY</th>
<th>1</th>
<th>2</th>
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</thead>
<tbody>
<tr>
<td>Lm</td>
<td>1.825</td>
<td>5.475</td>
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<tr>
<td>Lm/m²</td>
<td>1.3</td>
<td>1.4</td>
</tr>
<tr>
<td>Uo</td>
<td>9.6</td>
<td>50.8</td>
</tr>
<tr>
<td>UI</td>
<td>74.2</td>
<td>71.7</td>
</tr>
<tr>
<td>TI</td>
<td>5.4</td>
<td>Conserving position: -22.375, 1.125, 1.500 m</td>
</tr>
</tbody>
</table>

Schema

Sapphire 2/Flat Glass/1963/SON-T+2/150/125/-35
Effect of Street Lighting on Bats

General information: Standard CEN

Road details

Arrangement:  
No. of lanes: 2  
Lane width: 3.650 m  
Road width: 7.300 m  

Calculation: Luminance

Luminance details

Spacing: 31.000 m  
Height: 4.000 m  
Overhang: 0.000 m  
Setback: -1.500 m  

Inclination: 0°

Type: Sapphire 2

Reflector: 1543

Source: SON-T+  
Wattage: 150 W  
Fux: 17.5 km  
NF: 0.87

Summary

Luminance

Obly 1.823 m  
Lum: 1.4  
Vp: 4.9  
UI: 74.2  

TI: 9.3%  
Position: -1.500, 1.420, 1.500 m

Schema

TURBO Light  
User: me  
Page 1 / 1  
04/01/2008 10:46
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Appendix 1: Lighting Levels with Unshielded Sapphire Luminaires.

Project: Lighting for bats - Companion Calculations

General information: Standard CEN

Road details

<table>
<thead>
<tr>
<th>Arrangement</th>
<th>Driving</th>
<th>Way</th>
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<td></td>
<td>X</td>
<td>X</td>
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</table>

<table>
<thead>
<tr>
<th>No. of lanes</th>
<th>Lane width</th>
<th>Road width</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>3.650 m</td>
<td>7.300 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Reflode</th>
<th>Qo</th>
</tr>
</thead>
<tbody>
<tr>
<td>C200T</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Calculation: Luminance

<table>
<thead>
<tr>
<th>Spacing</th>
<th>Height</th>
<th>Overhang</th>
<th>Setback</th>
</tr>
</thead>
<tbody>
<tr>
<td>44.000 m</td>
<td>10.000 m</td>
<td>0.000 m</td>
<td>-1.000 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>Protector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sapphire 2</td>
<td>Low Profile Glass</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Source</th>
<th>Wattage</th>
<th>Flux</th>
</tr>
</thead>
<tbody>
<tr>
<td>SON-T+</td>
<td>150 W</td>
<td>17.5 lm</td>
</tr>
</tbody>
</table>

Summary

<table>
<thead>
<tr>
<th>Lumen</th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obey</td>
<td>1.623</td>
<td>3.472</td>
</tr>
<tr>
<td>LAve</td>
<td>1.2</td>
<td>1.3</td>
</tr>
<tr>
<td>Up</td>
<td>43.6</td>
<td>45.4</td>
</tr>
<tr>
<td>Ui</td>
<td>74.6</td>
<td>72.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tl</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>15.0</td>
<td></td>
</tr>
</tbody>
</table>

Observer position: -20.370; 1.020; 1.000 m

Schema

[Schematic diagram of street lighting setup]

Matt Emery

Urbis Lighting Ltd
Effect of Street Lighting on Bats

Appendix 1 - Lighting Levels with Shielded Sapphire Luminaire.

Project: Lighting for bats - Companion Calculations

General information: Standard CEN

Road details

<table>
<thead>
<tr>
<th>Arrangement:</th>
<th>Driving:</th>
<th>Way:</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of lanes:</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Lane width:</td>
<td>3.600 m</td>
<td></td>
</tr>
<tr>
<td>Road width:</td>
<td>7.000 m</td>
<td></td>
</tr>
<tr>
<td>Height:</td>
<td>C200T</td>
<td></td>
</tr>
<tr>
<td>Qo:</td>
<td>0.070</td>
<td></td>
</tr>
<tr>
<td>Calculation:</td>
<td>Luminaire</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Illuminance (Z Positive)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hemi-sph. III</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ti</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Illuminance (Y Positive)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Semi-obj. III</td>
<td></td>
</tr>
</tbody>
</table>

Luminaire details

| Spacing: | 35.000 m |
| Height:  | 10.000 m |
| Overhang:| 0.000 m  |
| Setback: | -1.000 m |
| Inclination: | 0.0 |

Description: Sapphire 2, 150W SON-T, LPG Protector, Type 1523 Reflector - With

Flux: 17.5 Wm² Np: 0.07

Summary

Luminaire

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>ObsV</td>
<td>1.925</td>
<td>5.475 m</td>
</tr>
<tr>
<td>LAvE</td>
<td>1.2</td>
<td>0.00</td>
</tr>
<tr>
<td>Up</td>
<td>54.2</td>
<td>55.1</td>
</tr>
<tr>
<td>UI</td>
<td>70.2</td>
<td>80.7</td>
</tr>
<tr>
<td>Ti</td>
<td>9.1</td>
<td>%</td>
</tr>
</tbody>
</table>

Observer position: -23.375; 1.835; 1.835 m

Schema

Sapphire 2, 150W SON-T, LPG Protector, Type 1523 Reflector - With 120mm KII
Effect of Street Lighting on Bats

Appendix 1 - Lighting Levels with Sapphire 1 Luminaires and No Internal Louvres.

General information : Standard CEN

Road details

Arrangement : 
Driving : 
Way :
Road width : 9.00 m

Calculation :  
Luminance
Illuminance (Z Positive)
Hemi-sph. ill.
Ti
Illuminance (Y Positive)
Semi-octl. ill.

Luminance details

Spacing : 38.00 m  Height : 6.00 m  Overhang : 0.300 m  Setback : 0.600 m

Induction : 30

Type : Sapphire 1

Protector : Low Profile Glass
Setting : 150°-25°

Source : SON-T+  Wattage : 70 W  Flux : 6.1 km  MF : 0.83

Summary

- Illuminance
  - Min : 1.73 lux
  - E Ave : 7.69 lux

Schema

![Diagram of lighting setup with Sapphire 1 Low Profile Glass and parameters]
Effect of Street Lighting on Bats

Appendix 1 - Lighting Levels with Sapphire 1 Luminaires and Internal Louvre.

General information: Standard CEN

Road details

Arrangement: [diagram]
Driving: [diagram]
Way: [diagram]
Road width: 9.500 m
Calculation: □ Luminance
☑ Illuminance (Z Positive)
□ Hemi-sph. Ill.
□ Ti
□ Illuminance (Y Positive)
□ Semi-Sph. Ill.

Luminance details

Spacing: 29.000 m
Height: 6.000 m
Overhang: 0.300 m
Setback: 0.600 m
Inclination: 30°

Description: SAPH 170W SONT. LG5, Type 1632 Reflector - With Int. Rear Louvre

Summary

- Illuminance
  EM1: 2.15 lux
  EM2: 7.50 lux

Schema

[diagram of SAPH 170W SONT. LG5, Type 1632 Reflector - With Int. Rear Louvre]
Effect of Street Lighting on Bats

General information: Standard CEN

Road data:
- Arrangement: [ ]
- Driving: [ ]
- Way: [X]
- No. of lanes: 2
- Lane width: 3.650 m
- Road width: 7.300 m
- Calculation: [ ]
- Luminance
- Illuminance (Z Positive)
- Hemi-sph. Ill.
- [X] Ti
- Illuminance (Y Positive)
- Semi-obj. Ill.

Luminaires details:
- Spacing: 34.000 m
- Height: 10.000 m
- Overhang: 0.000 m
- Setback: -1.000 m
- Inclination: 0.0
- Type: ZX
- Protector: Flat Glass
- Reflector: 1312
- Source: SON-T+ 150 W
- Wattage: 150 W
- Flux: 17.5 km
- MP: 0.87

Summary:
- Luminance:
  - 1
  - 2
- Obey: 1.625 5.475 m
- LAv: 1.1 1.1 cd/m²
- Up: 76.6 65.4 %
- L: 70.6 70.7 %
- Ti: 5.3 %
- Observer position: -23.370; 5.475; 1.000 m

Schema:

![Diagram of street lighting and bat movement](image)
Effect of Street Lighting on Bats

Matt Emery 23 Urbis Lighting Ltd

General information: Standard CEN

Road details

Arrangement:  x
Driving:  x
Way:  x

No. of lanes: 2
Lane width: 3.600 m
Road width: 7.300 m

Rf: 0.07
Calculation: Luminance

Luminance details

Spacing: 20.000 m
Height: 10.000 m
Overhang: 0.000 m
Setback: -1.000 m

Description: ZK2 150W SON-T, Flat Glass Protector, type 13/1 reflector - with Louvre

274573
Fm: 17.5
No.: 0.57

Summary

\[
\begin{array}{c|cc}
& 1 & 2 \\
\text{Obv} & 1.925 & 5.475 m \\
\text{LAv} & 1.9 & 1.0 \text{°} \\
\text{Up} & 45.5 & 43.4 % \\
\text{U} & 78.7 & 81.4 % \\
\text{Ti} & 0.7 & 11.8 %
\end{array}
\]

Observer position: -23.375; 5.475; 1.800 m

Scheme

ZK2 150W SON-T, Flat Glass Protector, type 13/12 reflector - with Louvre
Effect of Street Lighting on Bats

References

The Institute of Lighting Engineers (2007) *Bat & Lighting in the UK*

Jones, J. (2000) *The impact of Lighting on Bats*