Creating the future of transport

CSS Street Lighting Project SL1/2007
Published Project Report PPR380

Review of the class and quality of street lighting

G I Crabb, R Beaumont and D Webster

Transport Research Laboratory

PUBLISHED PROJECT REPORT PPR 380

Review of the class and quality of street lighting

by G I Crabb, R Beaumont and D Webster (TRL)

Prepared for: Project Record:	**CSS SL1/07**
	Review of class and quality of street lighting on all road types
Client:	**CSSLG, UKLB, SCOTS, ILE and TfL**

This Published Report has been prepared for CSSLG, UKLB, SCOTS, ILE and TfL. Published Project Reports are written primarily for the Client rather than for a general audience and are published with the Client's approval.

The views expressed are those of the author(s) and not necessarily those of CSSLG, UKLB, SCOTS, ILE or TfL.

	Name	Date Approved
Project Manager	G I Crabb	17/10/2008
Technical Referee	Alex Wright	17/10/2008

When purchased in hard copy, this publication is printed on paper that is FSC (Forest Stewardship Council) registered and TCF (Totally Chlorine Free) registered.

Foreword

In pursuing its goals of providing advice and guidance to lighting practitioners, the CSS Lighting Group, in partnership with SCOTS, Transport Scotland, ILE, and TfL has commissioned five research projects to advance some significant lighting issues.

This project is the first in that series and addresses the class and quality of street lighting on local road networks.

When developing lighting schemes designers can draw on guidance provided in CEN/TR 13201-1:2004, BS EN 13201-2:2003 and BS 5489-1:2003 + A2:2008. Although these standards provide advice on good lighting practice, they are not mandatory.

The project aims to provide Local Authorities with current and relevant information on which to base decisions on the lighting levels to specify for the six road hierarchy categories defined in “Well Maintained Highways” (UKRB, 2005).

Lighting should match the variable needs of traffic and pedestrians throughout the day and night on different road types, while minimising the use of energy and maintaining road safety and security. The report consequently gives consideration to the benefits and disadvantages in using variable lighting levels.

TRL Ltd was commissioned to undertake the work which was managed on behalf of CSS-LG by Dave Coatham from ILE and Glyn Williams from Cornwall CC.

The input of those people from the twenty two authorities from throughout the UK, listed at appendix E, must be acknowledged for their invaluable support in assembling the background data for this work.

An executive summary is provided at page iii and recommendations on page iv.

The CSS-LG hopes that the document proves to be valuable in assisting lighting engineers in their work, while also raising an awareness of some the broader issues.

Copies of this report can be downloaded at www.trl.co.uk/store

Contents

Executive summary

Introduction

TRL Ltd was commissioned by Transport for London to carry out this research, which forms part of a program of research funded by the County Surveyors Society Lighting Group, the UK Lighting Board, the Society for Chief Officers of Transportation in Scotland, the Institution of Lighting Engineers and Transport for London.

The project was intended to provide Local Authorities with current and relevant information on which to base decisions on the lighting levels to specify for the six road hierarchy categories defined in "Well Maintained Highways" (UKRB, 2005).

The guidance was to include consideration of the benefits and disadvantages in using variable lighting levels. The lighting provided needs to match the varying needs of traffic and pedestrian flows, throughout the day and night, on the different road types, while minimising the use of energy and while maintaining road safety and security.

The methodology for the research was divided into four main parts:

- a desk study of standards, guidance documents, research papers,
- a consultation exercise with a number of local authorities to assess how the standards are applied in practice and where improvements might be made,
- a study of the range and cost of currently available lighting equipment, together with estimates of energy and whole-life costs of a range of systems,
- and dissemination of recommendations in this report.

Background

When developing lighting schemes local authorities can draw on guidance provided in the European Standard (BSI, 2003a), and the British Standard Code of Practice (BSI, 2003b) (which complements the European Standard by making specific recommendations for UK conditions). Although these standards provide advice on good lighting practice, they are not mandatory.

These standards recognise the need for lighting authorities to develop schemes with designs that are appropriate for the application. They provide a greater number of lighting classes than the former British Standard (BSI, 1992), and in principle should allow better matching of the lighting to the class and use of a road. Hence they could assist in the avoidance of over-lighting and excessive energy consumption. Guidance is also given in these standards regarding the use of dimming at times of low traffic and the use of "white" light in mixed-use areas.

Further advice has also been developed covering the maintenance and operation of road lighting, including the UK Lighting Board's "Well Lit Highways" (UKLB, 2004), the Institution of Lighting Engineers' "Code of practice for variable lighting levels for highways" (ILE, 2005) and "Street lighting – invest to save" (ILE, 2006). Again, considering energy efficiency, the latter of these documents provides advice for local highway authorities considering removal of lighting or reduction of operating hours.

However, there was concern that the guidance and advice is being applied conservatively when designing new and replacement lighting schemes. This may be resulting in some lighting schemes having excessive lighting levels, leading to waste of energy, and increased potential for visual intrusion and light pollution.

The technology of street lighting is, and has recently been, changing rapidly with the availability of improved high-pressure discharge lamps and luminaires offering improved control of the colour and distribution of the light and longer life. Electronic control gear inherently wastes less energy than traditional electromagnetic ballasts and provides a higher power factor while facilitating the implementation of multi-step dimming and introducing the possibility of remote control and monitoring of the lighting. These improvements can be used, either to increase lighting levels or to reduce energy consumption.

After due consideration of the standards, guidance documents, local authority questionnaire returns and a whole life cost comparison of four types of lighting system the project arrived at a set of recommendations for specifiers of new or improved lighting schemes.

Recommendations

This research has shown that the current standards and published guidance allow considerable flexibility in specifying lighting levels.

- Local authorities should use this flexibility to set minimum lighting levels that will satisfy users without compromising safety, i.e. lighting should not be over-specified.
- Greater use should be made of CEN/TR 13201-1 which will result in better matching to requirements and allow savings in some areas.
- The impending revision of the British Standard should consider adopting more of the flexibility provided by CEN/TR 13201-1.
- Full use should be made of the guidance contained in the ILE guidance on variable lighting and its "Invest to Save" advice note.

When replacing lighting or installing new lighting local authorities should:

- Replace low-pressure sodium lamps in inefficient luminaires with high-pressure sodium, ceramic metal halide or other small lamps in efficient luminaires providing good light control. This should allow the use of lower wattage lamps or wider column spacings.
- Select optically efficient luminaires which direct most of the light where it is needed. This will permit the use of the lowest wattage lamps which will satisfy the required lighting class. It will also reduce problems of light intrusion.
- Make use of the freedom to reduce the lighting class below that which would otherwise be specified when switching to "white" light. This is particularly important in residential streets, which are lit to a low level. This class reduction may permit the use of lower wattage lamps or greater column spacings. This reduction in class has been shown by research not to have a deleterious effect on visibility.
- Specify lamps of the minimum practical wattage, particularly if moving to "white" light. Replacement of inefficient with more efficient luminaires should allow this.
- Have a preference to select "white" light for residential and town centre areas and HPS for traffic routes.
- Avoid intrusive light spill, particularly in residential streets, by using appropriate luminaires and installation geometries.
- Specify electronic control gear, but look carefully at predicted life when calculating whole-life costs.
- Consider installing dimming where road use varies widely during lighting hours.
- Consider installing remote control and monitoring equipment.
- Carry out a whole-life-costing exercise to compare the costs of these options, along the lines of the comparisons presented in this report, before making the decision as to which equipment to instal.
- Not assume that brighter or more lighting will automatically reduce levels of crime.

Abstract

TRL was commissioned by TfL to carry out research into the class and quality of street lighting on all types of road on behalf of the sponsoring group. The methodology included a review of standards and guidance documents, a review of costs of a range of lighting equipment and a survey of local authorities' policies and specifications. The report presents the results of the desk study and an analysis of the questionnaire returns. The cost information was used in a whole-life-cost calculation of the hardware and energy costs over a 30-year life, to compare four types of lighting system. These were conventional HPS lamps with electromagnetic gear, HPS with non-dimming electronic gear, Philips Cosmopolis White lamps with similar electronic gear and an HPS system with electronic gear, part-night dimming and central control and monitoring.

The results showed that most of the authorities specify selection of lighting classes within the range of the current British Standard, but that this standard is relatively inflexible compared to the parallel European document. This may in some cases result in the selection of unnecessarily high lighting classes. Most authorities have policies on lamp type, but few have policies on dimming, full or part-night extinguishing, central monitoring and control or passive safety.

The WLC exercise demonstrated that although the more "advanced" systems use the least energy, higher initial costs result in WLCs over 30 years being similar. There should therefore be no serious financial impediment to the installation of the more advanced systems. The report concludes with a set of recommendations which should help local authorities specify optimum lighting for all lighting situations.

1 Introduction

The objective of this project was to provide Local Authorities with current and relevant information on which to base decisions on appropriate lighting levels to specify for new and replacement street lighting. These lighting levels should match the varying needs of traffic and pedestrian flows, throughout the day and night, on the different road types, while minimising the use of energy and while maintaining road safety and security.

TRL Ltd was commissioned by Transport for London to carry out this research, which forms part of a program of street lighting research funded by the County Surveyors Society Lighting Group, the UK Lighting Board, the Society for Chief Officers of Transportation in Scotland, the Highways Agency and Transport for London.

The methodology for the research was divided into four main parts:

- a desk study of standards, guidance documents, research papers (reported in Section 2),
- a consultation exercise with a number of local authorities to assess how the standards are applied in practice and where improvements might be made (reported in Section 3),
- a study of the range and cost of currently available lighting equipment, together with estimates of energy and whole-life costs of a range of systems (reported in Section 4),
- and dissemination of recommendations in this report (Section 5).

A glossary of technical terms used is included in Appendix A.

1.1 Background

When developing lighting schemes Local Authorities can draw on guidance provided in the European Standard (BSI, 2003a), and the British Standard Code of Practice (BSI, 2003b) (which complements the European Standard by making specific recommendations for UK conditions). Although these standards provide advice on good lighting practice, they are not mandatory.

These standards recognise the need for lighting authorities to develop schemes with designs that are appropriate for the application. They provide a greater number of lighting classes than the former British Standard (BSI, 1992), and in principle should allow better matching of the lighting to the class and use of a road. Hence they could assist in the avoidance of over-lighting and excessive energy consumption. Guidance is also given in these standards regarding the use of dimming at times of low traffic and the use of "white" light in mixed-use areas.

Further advice has also been developed covering the maintenance and operation of road lighting, including the UK Lighting Board's "Well Lit Highways" (UKLB, 2004), the Institution of Lighting Engineers' "Code of practice for variable lighting levels for highways" (ILE, 2005) and "Street lighting – invest to save" (ILE, 2006). Again, considering energy efficiency, the latter of these documents provides advice for local highway authorities considering removal of lighting or reduction of operating hours.

However, there is concern that the guidance and advice is being applied conservatively when designing new and replacement lighting schemes. This may result in such lighting schemes having excessive lighting levels, leading to waste of energy, and increased potential for visual intrusion and light pollution.

The technology of street lighting is, and has recently been, changing rapidly with the availability of improved high-pressure discharge lamps and luminaires offering improved control of the colour and distribution of the light and longer life. Electronic control gear inherently wastes less energy than traditional electromagnetic ballasts and provides a higher power factor while facilitating the implementation of multi-step dimming and introducing the possibility of remote control and monitoring of the lighting. These improvements can be used, either to increase lighting levels or to reduce energy consumption.

2 Review of standards and guidance documents

A glossary of the technical terms used in this report is provided in Appendix A. This includes types of lamp, lighting equipment, photometry and terms used in the street lighting standards.

2.1 The purpose of street lighting

The current British Standard (see Section 2.2) provides a concise description of the purpose of street lighting:

> *Road lighting encompasses the lighting of all types of highways and public thoroughfares, assisting traffic safety and ease of passage for all users. It also has a wider social role, helping to reduce crime and the fear of crime, and can contribute to commercial and social use at night of town centres and tourist locations. Road lighting should reveal all the features of the road and traffic that are important to the different types of road user, including pedestrians and police.*

2.2 British and European standards

A range of guidance documents exists to guide the specifiers and designers of street lighting schemes. The most fundamental of these are the British and European Standards. The current standards were published in 2003 and comprise the European Standard, published as BS EN 13201 (BSI, 2003a), in three parts, together with "published document" PD CEN\TR 13201-1 (BSI, 2004) and the British Standard Code of Practice, BS 5489 (BSI, 2003b) in two parts.

The three parts of BS EN 13201 are entitled:

- "Road lighting — Part 2: Performance requirements",
- "Road lighting — Part 3: Calculation of performance" and
- "Road lighting — Part 4: Performance measurements",

and PD CEN\TR 13201-1 is entitled

- "Road lighting - Part 1: Selection of lighting classes".

(A "CEN\TR" is a CEN Technical Report, which does not have the status of a standard. A conflicting national standard may exist alongside such a document, whereas an EN standard carries with it the obligation to be implemented at national level by being given the status of a national standard and by withdrawal of any conflicting national standards.)

The European Standard superseded many clauses in the ten parts of the previous BS 5489 (BSI, 1992), which were all withdrawn. A new BS 5489 "Code of practice for the design of road lighting" was published in 2003 in two parts:

- Part 1: Lighting of roads and public amenity areas and
- Part 2: Lighting of tunnels

This new edition of BS 5489 facilitates the use of BS EN 13201 in the UK. As well as giving recommendations on the general principles, aesthetic and environmental aspects of lighting, it provides guidance on the appropriate selection of the various lighting classes set out in BS EN 13201 for a wide range of lighting situations. Thus BS 5489 to some extent supplants the guidance in CEN\TR 13201-1 on the selection of lighting classes, but makes numerous references to it for further information. In essence BS EN 13201 sets out the specifications for several types of lighting classes, while BS 5489 recommends how these classes may be applied to road and traffic categories defined for the UK.

2.2.1 Definition of lighting classes

There are two main bases for the design of street lighting embodied in the current standards. The first is relevant to routes carrying mainly vehicular traffic ("traffic routes") and is based on the luminance of the road surface. The second is relevant to all other areas, which include conflict areas, such as junctions, minor and residential roads, urban centres and foot and cycle paths. For these areas the basis is that of illuminance, the light flux incident on, generally, with some exceptions, horizontal surfaces.

In general BS EN 13201 defines a slightly wider range of lighting levels, at both ends of the scales, than the superseded version of BS5489 and about twice as many classes of lighting level. This is true for both luminance and illuminance classes. This gives greater scope for accurate matching of lighting levels to requirements than previously. The facility to vary lighting levels to match the requirements of different levels-of-use during different periods of the night was also introduced. This facility was actively discouraged in the superseded version of BS 5489.

2.2.1.1 Luminance classes

The principle of lighting based on luminance is concisely summarised in Appendix C of BS 5489-Part 1:2003:

> *The aim of road lighting for vehicular traffic is generally to reveal objects in silhouette, and this is maximized when the illuminance of vertical and near vertical surfaces is as low as possible. This is achieved at most positions on the road as a result of the inter-relation of the spacing of the luminaires, their mounting height and their light distribution. A light coloured object can appear in reversed silhouette and there might be a certain reflectance of the object which will give it the same luminance as that of the road forming the background, making it disappear. In practice, this is unlikely to occur, firstly because objects are viewed against a considerable stretch of road or road surrounds, which will show some unevenness of luminance, and secondly because objects are rarely of uniform reflectance. In addition, as the driver moves position, the background against which the object is viewed changes, thereby helping to reveal the object.*

BSEN 13201 - Part 2 sets out specifications for six "ME" lighting classes, for dry roads, which are based on average luminance and luminance uniformity, together with a maximum "Threshold Increment", which is a parameter designed to control glare and a "Surround Ratio". The latter controls the minimum luminance of a strip adjacent to the carriageway when there are no traffic areas with their own requirements adjacent to the carriageway. Such areas include footways, cycleways or emergency lanes. The ME classes range in average luminance from 2.0 cd/m^2 to 0.3cd/m^2.

"MEW" classes for wet roads are also defined. These are intended to be used "*where the road surface is damp or wet for a significant part of the hours of darkness*".

2.2.1.2 Illuminance classes

For other than traffic routes, luminance classes are not considered an appropriate design method. This is mainly because the background against which hazards are seen is not so well defined. In these situations the intention of the lighting is to illuminate objects rather than backgrounds. For these classes the illuminance and the orientation of the surface illuminated are defined.

BS EN 13201 defines the following classes based on illuminance:

- CE classes (range 7.5 lux 50 lux *horizontal plane* illuminance, with a uniformity requirement) apply to motorised vehicles, but in "conflict areas" such as shopping streets complex intersections, roundabouts and queuing areas. They are also relevant to pedestrians and cyclists.

- S and A classes relate to pedestrians and pedal cyclists on footways, cycle ways emergency lanes and other road areas lying separately along the carriageway of a traffic route, residential road, pedestrian street etc. The S and A classes reflect different priorities for the road lighting. The S classes range from 15 lux to 2 lux *horizontal plane* illuminance, but there is a further class of unspecified illuminance level. There are also minimum and maximum illuminance requirements for each class, designed to control uniformity. The A classes relate to *hemispherical* illuminance and range from 5 lux to 1 lux, again with a further unspecified class. However, BS 5489-Part 1 specifies that the *horizontal plane* illuminance classes should be used in preference and which will provide adequate vertical illuminance at the height of the human face, ensuring a high possibility of recognition.

- The ES classes are intended as additional classes for situations where public lighting is necessary for the identification of persons and objects and in road areas with a higher than normal crime risk. These are based on *semi-cylindrical* illuminance, ranging from 10 lux to 0.5 lux. In BS5489 the use of these classes is restricted to areas with particular problems of crime and personal safety and their use is not recommended other than in exceptional circumstances.

- The EV classes are based on *vertical plane* illuminance, ranging from 50 lux to 0.5 lux. They are intended as additional classes for situations where vertical surfaces need to be seen in such road areas as toll stations and interchange areas.

2.2.2 Selection of lighting classes

BS5489 Part 1 (BSI, 2003) gives guidance on the general principles of street lighting including aesthetic and technical aspects, statutory provisions and operation and maintenance. It provides guidance on the selection of appropriate lighting classes from those described in Section 2.2.1, for all types of highways and public thoroughfares including conflict areas, urban centres and routes solely for pedestrians and cyclists. The lighting of vehicular tunnels and underpasses is considered in Part 2 of the standard. There are additional recommendations for lighting around aerodromes, railways, harbours and navigable waterways.

For traffic routes, including motorways guidance is given in the form of table B2 specifying, in general, appropriate ME lighting classes from BS EN 13201-2. The lighting class is selected on the basis of the highway category, and for most of these categories, the average daily traffic. In specific cases the suggested lighting class is varied according to a range of parameters which include the number of carriageways, the frequency of intersections, and whether urban or rural. It is notable that the equivalent process detailed in CEN\TR 13201-1 allows a considerably wider range of class selection, taking account of the complexity of the visual field, the difficulty of the navigational task and the ambient illuminance. As an example, for motorways, only classes ME1 or ME2 can be selected using BS5489, whereas, depending principally on traffic flow, but also the parameters mentioned above, CEN\TR 13201-1 allows the selection of classes ranging from ME1 to ME5. If this approach were followed, much greater scope for dimming at times of low flow would be obtained. Similar situations pertain for the other traffic route categories in BS5489.

For "conflict areas", BS5489 provides Table B3 which maps the ME class of the lighting of the roads approaching the conflict, to a CE class which is one class higher in level (corresponding to a class number one lower). Table B1 of BS5489-Part 1 shows an equivalence of ME and CE classes with the *same* number. A modified version of this table including the specified "minimum maintained" average luminance and illuminance levels for each class is shown as Table 2.1 for reference. Inspection of the luminances and illuminances corresponding to these classes shows that the equivalence is based on an "average luminance coefficient", Q_0 equal to 0.07 (equivalent to a reflectance of 20%). This is the nominal value for the "representative British road surface" also quoted in the same standard.

Table 2.1 Lighting classes of comparable level (modified from BS5489-Part 1:2003)

ME Class		CE class		S class	
Class	$\bar{L}$ (cd/m^2)	Class	$\bar{E}$ (lx)	Class	$\bar{E}$ (lx)
-	-	CE0	50	-	-
ME1	2.0	CE1	30	-	-
ME2	1.5	CE2	20	-	-
ME3	1.0	CE3	15	S1	15
ME4	0.75	CE4	10	S2	10
ME5	0.5	CE5	7.5	S3	7.5
ME6	0.3	-	-	S4	5.0
-	-	-	-	S5	3.0
-	-	-	-	S6	2.0

For residential roads with uncontrolled parking and "subsidiary roads" (access roads, residential roads and associated pedestrian areas, footpaths and cycle tracks), where illuminance is specified, the appropriate S class is selected using Table B4 of BS5489-Part 1. The selection is based on traffic flow, local relative crime rate, the Environmental Zone E1 to E4 (defined in ILE, 2000 and reproduced here in Table 2.2) and whether the average colour rendering index (R_a) of the lighting is above or below 60. This is the chosen threshold for defining "white" light. Above this threshold one class lower lighting level can be selected. It is also specified that for urban and residential roads the colour rendering index should not be below 20, which effectively rules out the use of low-pressure sodium, which cannot render colours, being effectively monochromatic, in these areas.

Table 2.2 Environmental zone definitions (from ILE, 2000)

Category	Examples	Description
E1	Intrinsically dark landscapes	National Parks, Areas of Outstanding Natural Beauty, etc
E2	Low district brightness areas	Rural, small village, or relatively dark urban locations
E3	Medium district brightness areas	Small town centres or urban locations
E4	High district brightness areas	Town/city centres with high levels of night-time activity

2.3 Other guidance

2.3.1 ILE Code of practice for variable lighting levels

Two years after the publication of the British and European Standards the Institution of Lighting Engineers (ILE) published a code of practice for variable lighting levels (ILE, 2005). This built on the provisions for variable lighting introduced by the 2003 standards by providing advice and information on the choice of systems for variable lighting. The 2003 standards provide a wider range of lighting classes than in previous versions and provide for selection based on road category and traffic type together with traffic flow, with a suggestion that lower classes could be switched to at times when flows are lower. This ILE document takes this further, using the provisions of the standard to detail the advantages and disadvantages of variable lighting and its practical implementation. It goes on to consider authorities' "power to light", the legal implications of dimming, environmental and economic considerations, followed by guidance on equipment and the selection of appropriate levels and the practical application variable lighting.

The document highlights that although authorities are empowered to provide street lighting they do not have a legal duty to do so. There is also no statutory requirement to follow the standards or the guidance in any other document in setting lighting levels or hours of operation. However authorities do have a duty of care so adherence to a lighting policy based in the British Standard is advisable.

The environmental section describes how good choice of lamp and luminaire can reduce wasted light and glare. This may permit the selection of lower wattage lamps, which as well as dimming at appropriate times will reduce energy consumption. Both can also reduce environmental intrusion, which may be a statutory nuisance.

A possible obstacle to the implementation of dimming is the system for charging authorities for electricity for lighting based mainly on unmetered supplies. This system is described together with the alternatives. The main implication for systems using variable levels is that extra equipment will be required, to either meter the energy, or to calculate the amount used based on operating hours at the various levels. The reduction in energy use will be offset to some extent by the extra capital and running costs of this equipment and the extra complexity in negotiating satisfactory charging arrangements. Therefore whole-life costings of alternatives are required for comparison. A flowchart outlining the elements to be included in a cost-benefit analysis is presented. The document suggests that payback time is likely to be longer for installations using lower wattage lamps.

The discussion on equipment considers lamps, only some of which are practicably dimmable and most of which need to be stabilised at 100% output for several minutes before dimming. The amount by which the various types of discharge lamps can be dimmed varies and it is emphasised that the efficacy of the lamp falls with the output. The abilities of electromagnetic and electronic control gear are discussed. Electronic gear, while possibly more expensive, has lower losses when in operation and can provide starting and dimming capabilities. More advanced versions are programmable and can provide remote control and monitoring, which can provide benefits for the operator, but at the cost of the extra equipment.

Criteria for variable lighting are presented which make use of the British Standards, in particular the selection tables of Appendix B of BS5489-1:2003 (BSI, 2003). The parameters which vary between day and night, of use in selecting variable lighting levels, are discussed. Among these the principal ones are traffic flow and ambient luminance. The ILE document recommends that there should not ever be a difference of more than two classes between adjacent sections of road, even when the lighting level is reduced. This is based on a similar recommendation in PD CEN\TR 13201-1 (BSI, 2004) regarding adjacent sections. A greater change could possibly be achieved by staged reduction (Notwithstanding that the transition between lit and completely unlit areas is commonly abrupt on all road categories.) The importance of maintaining uniformity when lighting is dimmed is emphasised. This can be achieved by dimming all the lamps and not by turning off alternate lamps as has sometimes been done. A table is provided, based on the information given in Table B2 of BS5849-1:2003, showing how the lighting class might be varied with traffic flow on the main categories of road. Detailed guidance is given on the implementation of dimming, including the measurement of traffic flows, staged dimming and the application of dynamic dimming (controlled by real-time flows).

2.3.2 ILE Interim Advice Note - Street lighting – invest to save.

The ILE has also published an "Interim Advice Note - *Street lighting – Invest to Save. Reduction or removal of street lighting* (ILE, 2006). This advice note was prompted by the rapidly increasing cost of energy and the announcement by some local authorities that they were considering switching off some lighting for part of the night or completely. The main message of the advice note is "Do not switch off street lighting without due consideration", as the total cost to society could be increased rather than reduced by so doing. The document then proceeds to outline the factors which should be considered in reaching a decision and the alternatives to switching off.

In summary, possible beneficial effects of lighting on accidents, crime, fear of crime, promotion of use of public transport, cycling and walking, and other community benefits should be considered. The ILE presents reasons why it is not beneficial to turn off lighting in town centres. Dimming should be considered as an alternative. On the other hand, in rural areas where flows of all types of traffic are smaller, switching off for part or all of the night could be beneficial.

2.3.2.1 Reducing energy consumption

A number of options for saving energy while not compromising road safety are introduced. One suggestion is that the ambient illuminance threshold at which lighting is switched on by photocells should be reduced from historic settings of "on" at 70 lux and "off" at 35 lux to "on" at 35 lux and "off" at 16 lux. These levels would give adequate time for warm-up for currently available lamps, bearing in mind typical illumination levels of 20 lux in traffic and 7.5 lux in residential streets. This would reduce operation time and increase lamp life. However, this should not be done with low pressure sodium or mercury vapour lamps with electromagnetic ballasts, which have longer warm-up times. It is noted that many signs and bollards are lit 24-hours a day. Lower equipment costs now make it economic to switch these off during the day using photocells. It is also possible that high retroreflectivity will eliminate need for them to be lit.

The advice note points out that dimming can be cost-effective even with low-wattage lamps now that energy costs are high and projected to rise further. On traffic routes dimming could be implemented at all times other than during peak (design) flow. As flow peaks are of relatively short duration, it might be possible to dim for more than 50% of lighting hours. The importance of dimming uniformly and not, for example, switching off alternate luminaires, is explained. As in ILE (2005), the scope for variable lighting levels given in the standards is noted. This gives provision for the lighting class to be reduced by careful consideration of the type, use and location of the road.

There is discussion of the types of lamps to be used, which refers to BS5489. This standard recommends that all lighting should have a Colour Rendering Index (R_a) greater than 20, effectively precluding the use of low pressure sodium light, which is monochromatic ($R_a<0$). The standard also allows the use of one lighting class lower when lamps with an $R_a \geq 60$ ("white" light) are used on "subsidiary roads" (which are mainly residential). This is because the improved colour rendering has been demonstrated to benefit vision and in particular facial recognition, at low street lighting levels.

It is highlighted that lighting should not be replaced to the existing or higher standard, without review in accord with the current BS5489. Conversion of existing lighting is considered. It is stated to be important that, when replacing or refurbishing existing lighting, full use is made of modern lamps, luminaires and control gear. Improved optical design of luminaires designed for high-pressure discharge lamps can substantially increase the proportion of the light falling where it is required (which may permit the use of lower wattage lamps). It is recommended that electromagnetic control gear should be replaced by electronic gear, even in existing luminaires, for an energy saving in the region of 5%. This opportunity should be taken when replacing existing control gear. This will also increase the life and reliability of the lamps.

2.3.2.2 Disadvantages of switching-off

Various problems which may result from a temporary switch off are discussed. These include equipment failures due to moisture and unlit columns left as hazards. The repair costs may outweigh benefits. The electricity Distribution Network Operator may also have safety concerns. Electricity charges may be adversely changed under the different pattern of use. This may take the form of greatly raised standing charge for the unused but still connected service. There is also potential for 3rd party claims resulting from any collisions with unlit columns.

2.3.2.3 Alternatives to switching-off

Various alternatives to street lighting are discussed, which may mitigate lack of lighting. These include illuminated road studs or upgraded white lines on traffic routes with few pedestrians or cyclists. However the extra cost of these should be taken account of in decision making.

Possible reasons for permanent removal are considered, for example where traffic has substantially reduced. However, before implementation, full consultation with all affected parties will be essential. Speed limit signing may also need to be changed or added if the lighting is removed.

The powers and duties of a lighting authority, be it parish, town, district or borough council, are reviewed. In summary, an authority has a power, not a duty, to light and must act reasonably. It must, for example, light objects it places in the highway and must keep provided lighting in good repair so that it does not cause injury. To remove lighting the authority needs to be able to demonstrate why it no longer needed.

In conclusion authorities are asked to consider that it may initially cheaper to switch off lighting full or part-time but in the longer-term the dimming option may be preferable, thus the advocation "Invest to save".

2.4 Guidance from the CIE

2.4.1 Guide to the lighting of urban areas (CIE 136)(CIE, 2000)

This was published as a supplement to CIE 115 (CIE, 1995) (Described in Section 2.4.2). It is designed to cover the lighting requirements for urban areas, which is based on illuminance. It covers effects on crime and the fear of crime, which are claimed to be positive, although it also states that there are few, if any, conclusive studies of the real effect on crime, due to the extreme difficulties involved. These include the wide variety of types of crime and the difficulty in gathering sufficient properly controlled data to significantly identify an effect.

However, the report considers that public lighting was originally introduced in towns as a means of reducing crime and that public and police perception of a beneficial effect on crime is the major driver in the requests for improvements in urban lighting (particularly in residential and commercial areas), rather than any reduction in accidents.

A relatively high risk of accidents on urban and in particular, residential, streets is reported. This is suggested to be influenced by the large number of pedestrians, who are stated to be involved in a high percentage of all road accidents. However, there are also significant objections to lighting in some areas based on light intrusion (or "trespass") and a detrimental effect on wildlife. These may be offset in town centres, in particular by enhancement of civic pride, perception of security and tourism.

The document considers separately the requirements for residential, commercial, and industrial areas. Lighting recommendations are given based on horizontal illuminance and an alternative "semi-cylindrical luminance" at 1.5m above ground level. The CIE considers that instead of horizontal illuminance, the specification of vertical or preferably, semi-cylindrical illuminance more accurately represents the requirements of pedestrians. This is based on recognition of the characteristics of other pedestrians ("facial recognition") from sufficient distance to take avoiding action. This parameter is regarded as the most important lighting requirement for areas dominated by pedestrians.

For residential areas there is discussion of the aesthetic appearance of lighting equipment, by day as well as night. In particular poles and luminaires should be considered as a unit. Appropriate mounting heights and spacings should be considered, as should the benefit in reducing "clutter" if lighting equipment is integrated with other street furniture. The importance of good control of light distribution, avoiding intrusion while lighting the footway, is highlighted. (Many, if not most, existing systems using low-pressure sodium lamps in deep bowl luminaires completely disregard this problem). It should be possible to achieve this control without the need for retrofitted and possibly unsightly screens if proper consideration is given to the selection of luminaires and mounting heights to provide the required light distribution. Particularly in narrow streets the use of wall-mounted luminaires may be appropriate. Other considerations are the colour of the light, which impacts appearance, and problems of location where there are trees.

Particular requirements of shopping areas (described as "commercial"), town centres, semi-pedestrian and pedestrian areas are considered. Where there is mixed use the lighting requirements for vehicle traffic are given as similar to those in CIE115 (CIE, 1995), while where there is high pedestrian use levels should be higher by at least one class with proportionately increased spill light on footways. In these areas lighting is provided for both visibility and aesthetic purposes. There are more vertical surfaces needing illumination than in other areas. This can be provided by selection of suitable luminaires, but care is needed to avoid excessive glare. A range of mounting heights will be appropriate; examples are given for a wide range of mounting heights. The possibility of wall mounting (requiring permission of the building owner) is mentioned. The lighting in these areas should be chosen to enhance the visual scene. Light sources should be chosen for efficiency, life and colour rendering (which will generally imply the use of a "white" light source).

In industrial areas the roads are generally used infrequently at night. This favours the use of dimming outside peak traffic hours. Some owners of premises may rely on public lighting for security of premises. However, this will not normally be part of the design consideration. If security lighting is provided privately it is recommended that the horizontal illuminance does not exceed two lux and the vertical illumination on facades four lux for surfaces of typical reflectance of 15%.

2.4.2 Draft revision of CIE 115

The current CIE 115 (CIE, 1995) "Recommendations for the lighting of roads for motor and pedestrian traffic" sets out the lighting classes on which the current BS EN 13201-Part 2 (BSI, 2003a) are based. The draft document is currently under review and a new version is expected to be published in 2008. It seems likely that the content will be used, possibly in a modified form, in the next version of the European Standard. The draft CIE

115 acknowledges that the performance of lamps and luminaires has increased since the publication of the current version and that adaptive lighting is now technically feasible at reasonable cost.

Typical reductions in ”road usage costs” resulting mainly from accident savings from lighting are given as:

- Motorways and semi-motorways 20%
- Other roads for solely motorised traffic 25%
- All-purpose roads 30%

The purposes of lighting are stated to be: the safety of all road users by allowing perception of hazards; the orientation of pedestrians and recognition of other pedestrians and to give a sense of security; and improvement of environmental appearance both by day and by night.

The relative importance of these purposes varies with the type of road and the needs of motorists and pedestrians differ. Therefore they need to be given appropriate weightings.

The document introduces the concept of “Normal” and “Adaptive” lighting. Normal lighting is that appropriate to the most onerous conditions if the same level is to be applied throughout the hours of darkness. This is equivalent to the current design situation. It involves the selection of a class using CEN-TR 13201-1 or a national code of practice such as BS5489. Adaptive lighting is appropriate where the lighting is to be varied at different times according to a weighting, for example off-peak, during better weather, at the weekend, or when there is more ambient light. Here a lower class can be selected, based on the same type of class from which the “normal” class has been selected. Generally only the luminance should be varied, retaining the uniformity of the “normal” class.

Separate tables for traffic streets, conflict areas and pedestrian and low traffic areas are provided which introduce a new weighting concept into the selection of lighting classes for the “adaptive” condition. For example the classes M1 to M6, which are similar to the existing ME classes, can be selected by summing tabulated weights for the following parameters: speed, traffic volume, traffic composition, separation of carriageways, intersection density, parked vehicles, ambient luminance and visual guidance/traffic control. The sum of these weights is to be subtracted from six to yield the appropriate class number. Careful selection of the weights will yield a class between one and six.

Similar weighting processes are provided for conflict area classes and pedestrian and low traffic area classes.

This approach represents a progression from that given in CEN-TR 13201-1, which, as has been noted in Section 2.2.2, already provides greater flexibility than BS5489. Its adoption could result in considerably lower lighting classes, in many situations, than use of the current standards.

2.5 Lighting and crime

2.5.1 Home Office review

In some urban areas the introduction of street lighting or its improvement has been found to reduce crime. This applies mainly to residential areas. Research reviewed and analysed for the Home Office (Farrington and Welsh, 2002) concluded that improved lighting can “especially if well targeted to a high-crime area” be an effective method of reducing crime and also leads to an increase in perceived public safety and greater use of streets by law-abiding citizens. The studies chosen for analysis, which were selected for being considered well-controlled, included eight from the USA and five from Britain.

The average reduction in crime after lighting improvements, over all the studies was 20 percent compared with unchanged control areas. In the British studies the average decrease was 30 percent (the statistical significances are given at the 95 percent level) and the financial savings in two of these greatly exceeded the costs of improving the lighting. However, it is also revealed that day-time crime also reduced at least as much in the improved areas, so it is debatable whether the crime reductions were correlated with the increased luminance or some other factor. It has been suggested, for example, that the provision of lighting provides a psychological deterrent to crime by demonstrating that an area is improving in terms of community pride, social control and surveillance and by increasing the perceived risk of detection.

2.6 Experimental research into the use of white light and dimming

2.6.1 NumeLiTe

Two full-scale trials have recently been carried out at TRL to examine visual abilities under high-pressure sodium (HPS - conventional "yellow") and ceramic metal halide (CMH - "white") street lighting, under four lighting conditions, using electronic control gear with dimming (Crabb et al, 2005, 2006).

The first TRL trial, using 150W lamps, was part-funded by the EC, DfT and CSS and was part of the European project "NumeLiTe". The second trial, using 70W lamps, was an extension to the first under a DfT contract. The NumeLiTe project set out to develop and prove the feasibility of an optimal and energy efficient outdoor city lighting system based on a prototype ceramic metal halide lamp, but involving every aspect of street lighting and street lighting equipment from the physics and chemistry of the discharge lamp to the safety of the road user. The overall aim of the system was to reduce energy consumption and running costs while improving light quality and maintaining road safety. The consortium of eleven included academic and industrial partners, research institutes, and an urban authority.

The objective of the first TRL trial was to test the relative visual performance of road users under the prototype CMH and conventional HPS, at both full output and half output, to validate the safety of the CMH scheme with and without dimming. There was an expectation in the project brief that visual abilities would be enhanced under the white light, which would permit lower luminance and therefore less energy to be used by white lighting to achieve the same degree of safety. To this end, following an extensive literature review, two observational tasks were selected that were as close to real driving tasks as feasible. The second trial was an extension of the first to find the effects of lower lighting levels than could be included in the first trial.

Two types of observation were included in the trials. One measured the distance at which a small target (a 200mm diameter grey sphere of 26% reflectance) on the road was detected by an observer driving a car, and was considered mainly a test of central vision. The other measured the reaction time of observers to a luminance change in a "flip-dot" target in their peripheral vision. Figure 2.1 shows the general plan layout of the road used, the lighting and the area where the target positions were located. Five lighting columns were spaced 30m apart and each supported two luminaires at a height of 9m. The reflector for both lamp types was a prototype design optimised for the CMH lamp.

For the central target observations the car was driven by the subject at 30km/h and for the peripheral target observations the car was stationary. The speed of 30km/h was judged to be the highest practicable given the short run-in available and the need to achieve a constant speed.

Observations were made by six subjects, of a range of ages and both sexes, both of the small target, successively in each position on the road, and of the peripheral target. All observations were made from the driving seat of the vehicle. Figure 2.2 shows the vehicle used in the trials and the target used in the central vision observations, on the trial road, under both the HPS and the CMH lighting.

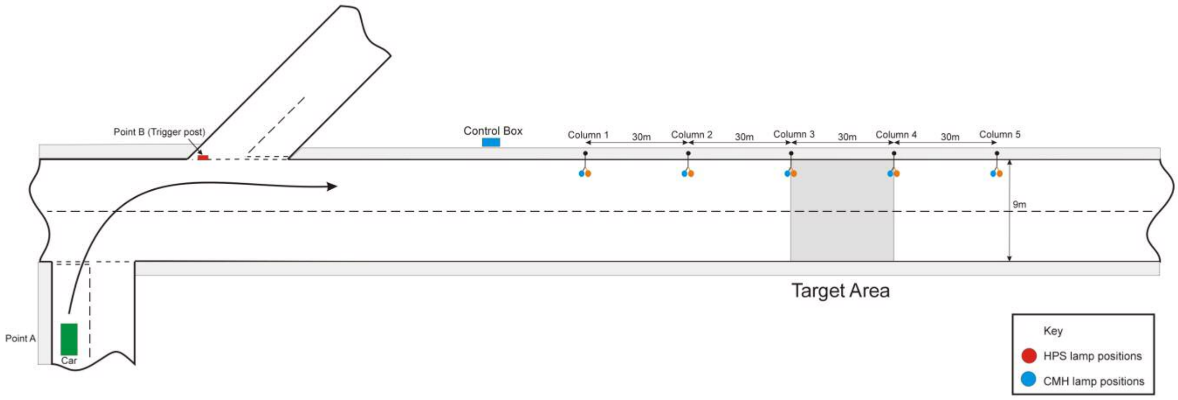

Figure 2.1 Schematic diagram of the track layout and target positions

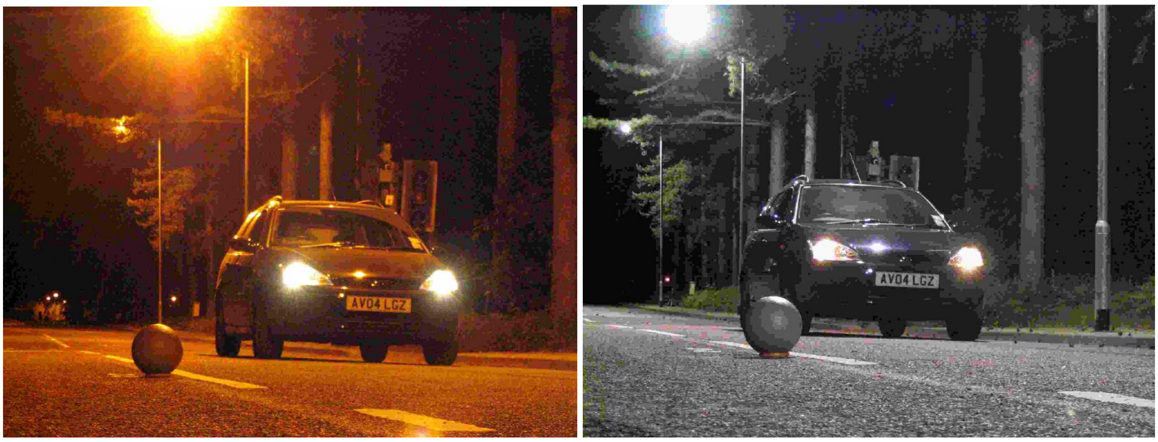

Figure 2.2 Test road, vehicle and target under HPS (left) and CMH (right) lighting

Full details of the experimental methods are given in Crabb *et al* (2005, 2006). The average luminances achieved on the test road for all the lighting conditions and the average small target detection distance are shown in Table 2.3.

Table 2.3 Average carriageway luminances and target detection distances in TRL trials

Lamp and Power	Average luminance (cd/m^2)	Average detection distance (m) (all observers and target positions)
CMH 40W (dimmed)	0.28	72.3
CMH 70W (full)	0.65	91.8
CMH 95W (dimmed)	0.43	87.5
CMH 150W (full)	0.94	83.2
HPS 40W (dimmed)	0.21	76.5
HPS 70W (full)	0.51	95.2
HPS 95W (dimmed)	0.52	98.2
HPS 150W (full)	1.2	96.8

An example of the reported results, which is a summary of the peripheral target reaction time data, is shown in Figure 2.3. This figure is a "box and whisker plot" in which the boxes show the interquartile range, with the mean denoted by a line. The whiskers show the full range of the data.

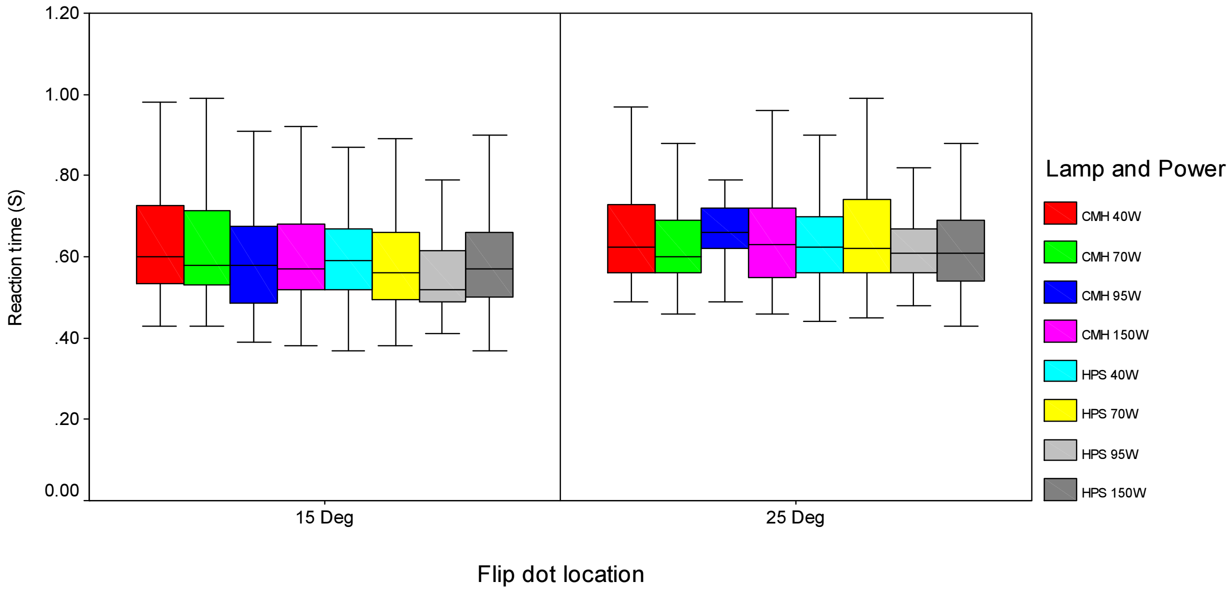

Figure 2.3 Average peripheral target reaction times for different lamp and power settings viewed at 15° and 25° off axis of fixation

Under the conditions examined, there was no significant (at the 95% confidence level) improvement in visual detection abilities under the white lighting at a similar average level to the HPS, in either the central or the peripheral visual fields. Also, there was little reduction in detection ability (measured as distance to a target when detected, when placed in various positions on the carriageway) with reducing illumination except at the lowest level of either light source. At this lowest level the result was biased by the significantly lower than average illumination of two target positions on the left of the carriageway where the luminance was below average. This highlights the importance of good uniformity of luminance if dimming is to be used.

A number of unresolved questions were raised by this study:

- What are the most appropriate measurable tasks for assessing the visual performance of a road user under current conditions?
- How much effect does the glare from approaching headlamps have on required lighting levels? Raynham (2004) has pointed out that the glare from oncoming headlamps can easily be several orders of magnitude higher than that deemed acceptable from street lighting. How could this be mitigated?
- How important is colour contrast in identifying hazards? This is not currently considered in the standards.
- What is the effect of traffic density on the optimum lighting level? How does this affect the potential for dimming at times of low flow?
- Is there a significant compensation effect with good lighting, which would lead to faster driving, which might increase the number of accidents in some circumstances?

It was discussed by Crabb and Steele (2006) in a paper entitled "Are street lighting levels too high" published in the TRL Research Review for 2005, that the flexibility provided by the current lighting standards should allow reductions in luminance on some roads when lighting equipment is replaced. Replacement of old luminaires with new ones of improved optical design will often allow the required lighting levels to be produced by lower wattage lamps. Improvements in the performance of available lamps and luminaires are likely as manufacturers bring out new products. During the early hours of the morning the answer to the question 'are street lighting levels to high' is likely to be "yes". We currently have the situation where highway lighting is designed to switch on either at set times or in response to the onset of low light levels. However, this means that large numbers of luminaires are on when most of the population is asleep. To date the use of dimming has been very limited, despite the success of schemes which have been implemented.

A more appropriate and technically feasible option proposed when traffic volumes are low during the night, was to dim lamps. The research described did not find any significant differences in detection distances or peripheral reaction times between high and low lighting levels under the conditions trialled. It was also of note that the observers often could not determine whether the lamps were at full power or dimmed. However these trials were primarily designed to look for differences in road user visual performance under the two lamp types of different spectral output and were unable to investigate the effects, for example, of higher speeds, coloured objects or opposing headlamps.

It was concluded in Crabb and Steele (2006) that the factors that are preventing wider uptake of this technology appear to be:

- Contractual factors – currently most lighting is not metered. The charge for lighting is based on the number and type of lamps and for how long they are switched on. If savings from dimming were to be realised then appropriate charging schemes would need to be in place.
- Capital costs of changing from electromagnetic ballasts to low-loss electronic control gear. This change is unlikely to occur until equipment is due for renewal, which is infrequent. However a large part of the UK lighting stock is overdue for replacement.
- Lack of a common standard for communicating with dimmable control gear which obstructs the flexibility of component supply.
- Concerns over reliability of relatively untried electronic systems.
- Capital costs of implementing network remote control and monitoring systems.

Therefore this paper considered that the challenge was not solely technical, but a combination of both economic and political factors.

2.6.2 Results of the EU MOVE project

The European MOVE project (Mesopic Optimisation of Visual Efficiency) was underway at the same time as the NumeLiTe project. This project is highly relevant to the choice of lamp for street lighting as it examined the spectral sensitivity of the human visual system in the range 10cd/m^2 to 0.01cd/m^2. This encompasses and is wider than the full range of street lighting luminances (typically 2cd/m^2 to about 0.1cd/m^2). The project involved experimental work at four European universities, a research institution and the UK National Physical Laboratory (NPL). Each laboratory carried out experiments using different visual tasks, with an emphasis on night-time driving performance. Finally, a combined analysis of all the test data was carried out. The results are fully documented in Volume 39, 2007 of the journal "Lighting Research and Technology". Individual papers describe the different experimental studies. The results relevant to night-driving, across all the studies, are given in a paper by Goodman *et al* (2007) in the same volume.

The paper collates results from observations using more than 100 observers in total. These examined detection threshold, reaction time and discrimination or recognition. All of the experiments used the background luminance levels 0.01, 0.1, 1 and 10 cd/m^2. A 2° target size, subtended at the eye, was used and the experiments used target eccentricities (from the optical axis of the eye) of 0° ("central vision" and 10° ("peripheral vision"). Both central and peripheral vision are important to performing the tasks of the road user. It is emphasised in the paper that, as with photopic ("daylight") photometry, mesopic photometry will only be valid under specific conditions, such as a particular target size and eccentricity and observer age. It was considered that any new system of photometry developed needed to be practical in terms of ease of application by road lighting engineers and equipment manufacturers. Both chromatic (target and background of different spectral distributions) and achromatic (target and background of identical spectral distributions) tasks were included in the experiments.

The experiments investigated:

- Contrast threshold (can it be seen?)
- Reaction time (how quickly?)
- Discrimination (what is it?)

A range of models was fitted to the resulting data and the simplest providing a satisfactory fit to the data for all three tasks was chosen. The model chosen (the "Photopic-Scotopic" or "PS" model) represents a transition between the two standardised, approximately Gaussian, curves describing human spectral sensitivity under adaptation to photopic (daylight) and scotopic (starlight) conditions.

For all three types of experiment it was found that off-axis, the spread of the modelled mesopic contrasts was much smaller than the photopic, demonstrating a better fit of the PS model. "On-axis" (central vision) the standard photopic curve provided a good fit to the data at all the tested levels above 0.01cd/m^2. The MOVE model is therefore only appropriate to peripheral and not central visual abilities.

The final MOVE model, representing visual ability 10° off-axis in the three tasks, represents a transition between the scotopic and photopic curves. The resulting mesopic luminance has been tabulated as a function of photopic background luminance and the ratio of scotopic to photopic (S/P) weighted luminances. An extract from this table is given in Table 2.4. The top half of the table shows modelled mesopic weighted luminances, for a range of photopic background luminance levels spanning the range of street lighting, in the columns. The mesopic luminances are tabulated for a range of S/P ratios in the rows. These S/P values have been chosen to represent the typical spectral outputs of lamps used in street lighting. The bottom half of the table shows the ratios between these mesopic luminances between three pairs of the selected LPS, HPS and MH lamps. It can be seen that, under the 10° off-axis condition specified, there is little difference between visual performances under the three spectrally different light sources at 3cd/m^2, but that the differences steadily increase as the background luminance reduces. For example, a level of 0.1cd/m^2, HPS is 1.25 times more effective than LPS, while MH is 1.8 times more effective than HPS.

Table 2.4 Modelled mesopic luminance values (cd/m^2)for selected lamp types at different photopic background luminances (after Goodman *et al* 2007)

	Background luminances	0.03	0.1	0.3	1	3
	S/P	**Mesopic luminance (cd/m2)**				
LPS	0.25	0.0075	0.064	0.234	0.874	2.81
HPS	0.55	0.0202	0.080	0.262	0.927	2.89
MH	2.25	0.0498	0.144	0.39	1.18	3.28
MH/HPS	Ratios	2.47	1.80	1.49	1.27	1.13
MH/LPS		6.64	2.25	1.67	1.35	1.17
HPS/LPS		2.69	1.25	1.12	1.06	1.03

The paper considers that the model is applicable to night driving in the range of road background luminances from 0.1cd/m^2 to 10cd/m^2. It is stated that use of the model to calculate the effective luminance of street lighting sources will result in a significant change in their apparent efficacy.

It should be remembered that for on-axis vision no spectral effect was found at any level above 0.01cd/m^2 and therefore the information in the table does not apply to the central visual field. However, the relative weighting that should be given to central and peripheral vision for road users at night is not known. However, there is evidence that peripheral vision is critically important in both the daytime and at night. The authors of the paper consider that use of the MOVE model will be relevant and practical for lighting engineers and specification bodies in applications such as road lighting, to improve lighting and enhance safety. They urge the CIE (the principal international body developing basic standards and procedures of metrology in the fields of light and lighting) to recommend adoption of a model for mesopic photometry of the form of the MOVE model.

2.6.3 Are street lighting levels too high? (Crabb and Steele, 2006)

This paper provides a review of the history of street lighting and street lighting standards. It discusses the benefits of street lighting and summarises recent practical research at TRL. Data presented in the paper on the growth of street lighting in Britain between 1923 and 1999, taken from an article by Mc Neill (1999), is shown in Table 2.5.

The energy use tabulated in Table 2.5 is that supplied locally to the lighting systems, so neglects electricity generation and transmission losses (for electricity typically 65% and for gas, production and transmission losses of 8%). In 1923 most of the lighting was gas, but by 1938 there were roughly equal numbers of gas and electric lamps, with electric systems producing more than twice as many useful lumens than gas, from less energy, even after taking account of electricity generation and transmission losses.

It can be seen that the length lit, the amount of useful light and average illuminance levels have increased at a very rapid rate since then. This increase has been facilitated mainly by improvements in lamp efficacy, as it can be seen that overall energy usage has increased surprisingly little over the same period. Another critical parameter affecting overall efficiency is the "utilisation factor" which represents the ratio of the lumens produced by the lamp to the useful lumens reaching the area required to be lit. The utilisation factor is largely a function of luminaire and lamp optical design, in particular the size of the lamp and the design of the reflector. The average utilisation factor has increased in recent years, facilitated by the greater use of smaller high-pressure sodium (HPS) and metal halide lamps in place of the much larger low pressure sodium lamps (LPS). It has also been driven by increasing concerns regarding more effective lighting, energy saving and reduction of intrusion and pollution due to stray light.

The data in Table 2.5 indicates scope for further improvements in utilisation factor. Typical modern luminaires for HPS and metal halide lamps can achieve factors of up to 0.6 or more, although this depends to some extent on the ratio of column spacing to road width as well as the luminaire design. Currently available LPS luminaires achieve in the region of 0.4. This is lower mainly due to constraints imposed by the much larger lamp.

Table 2.5 Energy use, efficiency and average illuminance of street lighting in Britain (after McNeill, 1999)

Year	Lit roads (1000 km)	Percent of area lit by electricity	Energy use (GWh)	Useful light (Glmh)	Overall efficiency (Lumens/watt)	Average utilisation factor	Average illuminance (Lux)
1923-4	23	22	2374	743	0.31	0.2	0.8
1938-9	32	50	1867	1,380	0.74	0.2	1.6
1953-4	46	76	1979	3,080	1.6	0.23	2
1968-9	75	98	1670	15,000	8.9	0.25	5.2
1983-4	110	99	2380	46,580	19.6	0.29	10.5
1998-9	160	100	2800	86,720	31	0.35	13.1

Where an installation using deep-bowl luminaires with LPS lamps is replaced by an installation using HPS or MH lamps in a well-controlled luminaire, the gain in efficiency of the luminaire should more than compensate for the relative loss in light output of the HPS lamps. Manufacturer's data suggests that a utilisation factor of 0.6 is achievable by an HPS or CMH installation, whereas deep-bowl luminaires with LPS lamps may only achieve 0.2. The light output of typically HPS lamps is about 100 lumens/watt compared with 150 lumens/watt for HPS.

2.7 Discussion

It is clear from the literature review that documents already exist that provide a comprehensive framework for good matching of street lighting levels to the requirements of road users. Making full use of these documents can minimise energy consumption while maintaining safety and security.

The current British and European (2003) standards allow considerable flexibility in the specification of street lighting on all types of road. More lighting levels are provided than were by the previous British Standard, although the range of levels covered is slightly wider than previously. There is also no discouragement, as previously existed, from dimming to a lower class when traffic or use conditions permit. However, it is notable that the Technical Report CEN TR13201-1 (see Section 2.2) provides considerably more flexibility in the setting of levels than the British Standard BS5489. It does this by allowing the selected class to be influenced, for example on traffic streets, by more factors, such as speed, traffic composition and the presence or absence of parked vehicles.

The revision of the CIE guidance (CIE115) soon to be published, takes this further, as described in Section 2.4.2, by basing "normal" lighting level on the most onerous condition for a given road and setting reduced "adaptive" levels when conditions are less onerous. This is done by developing weighting schemes for determining the adaptive level, based on similar factors to those mentioned above. Separate weightings have been developed for traffic streets, conflict areas and pedestrian and low traffic areas. It is likely that the guidance given in this new revision of CIE 115 will be taken account of when the current European and British lighting standards are revised. If the greater flexibility provided by the European documents was adopted in a future revision of BS5489, it is likely that average lighting levels and energy consumption could be reduced, without impairment of road safety, by adapting the lighting more closely to the conditions than is currently achieved.

The ILE "Code of practice for variable lighting levels" shows clearly how the provisions of the standards may be used to implement variable lighting, taking account of the various factors that should be considered in such a scheme. Additionally, the ILE "Advice Note on the reduction or removal of street lighting" provides useful guidance on safe ways of reducing energy consumption and alternatives to switching off.

The review of recent TRL research suggests that at the lighting levels required for traffic streets there is no safety or energy saving benefit from switching from HPS to "white" light, although lower levels than currently specified should be safe when traffic is light.

The MOVE project has confirmed a relative benefit of "white" light in off-axis (or peripheral) vision (used for detection), which increases as the lighting level falls. Although this effect has been shown not to occur in central vision (used for recognition) at practical lighting levels, recognition is likely to be enhanced by the more natural colour rendering of whiter light sources. This research suggests that when using whiter light it should be possible to reduce the lighting level more in the lowest street-lighting classes, without impairing its effectiveness, while providing reduced energy consumption. This finding is most appropriate to residential and quiet areas with little traffic, where lighting levels are lower.

It has also been shown that large efficiency gains have accrued and will continue to accrue with the steady replacement of inefficient luminaires with more efficient ones providing much more accurate control of the distribution of the emitted light. These gains should be used to reduce energy consumption, and not to increase lighting levels above those recommended in the guidance.

It should not be assumed that the installation of lighting, upgrading existing lighting or increasing lighting levels will automatically reduce levels of crime. Published research suggests that the effect of improved lighting on crime is extremely variable. Each case should be carefully considered. It can be effective if well-targeted to a high crime area. Doubts have been cast as to whether increased luminance is the reason for any improvement as it has been observed that day-time crime has also reduced in improved areas.

3 Consultation exercise by questionnaire

The consultation exercise was designed to determine the current lighting policies of a sample of local authorities, to assess how standards and guidance are used in practice and where improvements might be made. Initial consultation was carried out with a small number of selected authorities whose input was used to ensure that the questionnaire was focused and relevant to the objectives of the project.

The final questionnaire had seventeen main sections and many could be answered by selecting from a drop-down list. This minimised the number of possible answers and simplified the analysis. A copy of the final questionnaire, which was sent out to twenty-five local authorities by e-mail, is given in Appendix D. Twenty-two questionnaires were returned for analysis. The numbers received from each type of authority are shown in Table 3.1 and their locations are shown in Figure 3.1.

This section summarises these responses, while the discussion in Section 3.4 considers whether the responses provide evidence for aspects of policy and specifications that could be improved, and in particular whether there is any significant deviation from the standards.

Table 3.1 Questionnaire returns

Category	Number
English County/City Councils	11
English London Boroughs	3
Scottish Councils	5
Welsh Councils	2
Northern Ireland Government	1

3.1 Structure

The questionnaire was structured as follows:

- Policy guidelines for lighting classes on different categories of road
- Highest lighting class specified for carriageway road links
- Highest lighting class specified for carriageway conflict areas
- Highest lighting class specified for footway areas
- Factors considered in specifying lighting
- Intrusive or stray light policies
- Lighting equipment policies
- Maintenance policies
- General lighting questions

There were boxes for additional comments and the opportunity to add any other comments by email when the questionnaire was returned.

3.2 Results

A summary of the full responses is given in Appendix E. The following sections discuss the results and refer to the appendix as appropriate.

Figure 3.1 Location of councils surveyed

3.2.1 Policy guidelines

All of the respondents reported their use of current standards and professional guidelines for specifying lighting classes on different categories of road. BS 5489-2003 and BSEN13201 were specifically identified by all except one who indicated 'current standards and professional guidelines'.

3.2.2 Road hierarchy

Table 3.2 gives the road categorisation used in the following sections. This hierarchy is defined in "Well Maintained Highways" (WMH)(UKRB, 2005). This is almost identical to that used in BS 5489 for motorways and traffic routes, with the exception that Category 4b is covered by the "Subsidiary Roads" category in BS5489.

Table 3.2 Well-maintained highways road hierarchy

WMH Category	Description	General description
1	Motorway	Limited access motorway regulations apply
2	Strategic Route	Trunk and some Principal 'A' roads between Primary Destinations
3a	Main distributor	Major Urban Network and Inter-Primary Links Short - medium distance traffic
3b	Secondary Distributor	Classified Road(B and C class) and unclassified urban bus routes carrying local traffic with frontage access and frequent junctions
4a	Link Road	Roads linking between the Main and Secondary Distributor Network with frontage access and frequent junctions
4b	Local Access Road	Roads serving limited numbers of properties carrying only access traffic

3.2.3 Highest lighting classes specified for carriageway links

Local authorities were asked to state the highest lighting classes that they would specify for each road category. The most frequently specified "highest lighting classes" for carriageway links are given in Table 3.3 for each road category. These are compared with the ranges of expected classes defined in BS5489, also shown. The majority of the responses lie within the range specified in the standard. A summary of the levels specified in the current standard showing the approximate relationship of the ME, CE and S classes is also given in Table 2.1, on Page 8, for reference.

Table 3.3 Carriageway links

	Hierarchy	Most frequently specified class	% of responses	Total no. of responses	BS5489 specified	
					From	To
Cat 1	Motorway	ME1	83	6	ME1	ME2
Cat 2	Strategic	ME2	67	18	ME2	ME3
Cat 3a	Main distributor	ME2	44	18	ME2	ME3
Cat 3b	2nd distributor	ME3a	28	18	ME2	ME4
Cat 4a	Link road	ME4b	35	17	ME4/5	S1/S2
Cat 4b	Local access	S2	33	15	S1	S6

Notes: Table 3.3 includes response cases where more than one class was specified, as follows:

1. Cat 3b: ME3a or S2 (Ra 20 or above); or ME3b or S3, (Ra 60 or above) (1 respondent)
2. Cat 4a: ME4b or S1 (2 respondents)
3. Cat 4a: S2 or S3 for Ra ≥ 60 (1 respondent)
4. Cat 4b: ME4b or S1 (1 respondent)
5. Cat 4b: S4/S3/S2 depending on crime stats (1 respondent)
6. Cat 4b: S3 or S4 for Ra ≥ 60 (1 respondent)
7. Most commonly work to S2 when not using old BS (1 respondent)

3.2.4 Highest lighting classes specified for conflict areas

The most frequently specified "highest lighting classes" for conflict areas are given in Table 3.4, for each category of road. The results are again compared with the ranges of expected classes in BS5489. All of the highest specified classes are within the specified range of the standard.

Table 3.4 Carriageway conflict areas

	Hierarchy	Most frequently specified class	% of responses	Total no. of responses	BS5489 specified	
					From	To
Cat 1	Motorway	**CE0**	**75**	**4**	**CE0**	**CE1**
Cat 2	Strategic	**CE1**	**59**	**17**	**CE1**	**CE2**
Cat 3a	Main distributor	**CE1**	**56**	**18**	**CE1**	**CE2**
Cat 3b	2nd distributor	**CE2**	**44**	**16**	**CE1**	**CE3**
Cat 4a	Link road	**CE3**	**64**	**14**	**CE3**	**CE4**
Cat 4b	Local access	**CE4**	**36**	**14**	**S1**	**S6**

Notes: Table 3.4 includes the following where more than one class was specified:

1.	Cat 2 and Cat 3a	CE1 at Ra 20 or above
2.	Cat 2 and Cat 3a	CE1 and CE2
3.	Cat 3b.	CE2 at Ra 20 or above; or, CE3 at Ra 60 or above
4.	Cat 4b.	S3 at Ra 60 or above
5.	Cat 4b.	CE4 and S1
6.	All Cats.	To be determined by accident data

3.2.5 Footway hierarchy

The footway hierarchy defined in "Well Maintained Highways" is given in Table 3.5. This hierarchy is used in the next section to compare the responses with recommendations in the standards.

Table 3.5 Footway hierarchy

Category	Category Name	Description
1(a)	Prestige Walking Zones	Very busy areas of towns and cities with high public space and street scene contribution
1	Primary Walking Routes	Busy urban shopping and business areas and main pedestrian routes.
2	Secondary Walking Routes	Medium usage routes through local areas feeding into primary routes, local shopping centres etc
3	Link Footways	Linking local access footways through urban areas and busy rural footways
4	Local Access Footways	Footways associated with low usage, short estate roads to the main routes and cul-de-sacs.

3.2.6 Highest lighting classes specified for footways

Local authorities were asked to state the highest lighting class that they would specify for each category of footway. The most frequently specified highest lighting classes for footways for each category are given in Table 3.6. The results are compared with the ranges which would be expected using BS5489. In general there is no evidence of serious departure from the recommendations in the standards.

Table 3.6 Footways

	Hierarchy	Most frequently specified class	% of responses	Total no. of responses	BS5489 from	BS5489 to
Cat 1(a)	Prestige walking zone	CE1	50	16	CE1	CE2
Cat 1	Primary walking routes	CE2	38	16	CE2	CE3
Cat 2	2nd walking routes	S3	29	17	CE3/4	S1/2
Cat 3	Link footways	S3	37	19	S4	S5
Cat 4	Local access footways	S4	44	18	S2	S6

Notes: Table 3.6 includes the following response cases where more than one class is specified

1.	Cat 1a and Cat 1:	Hybrid – 37 to 43 lux at minimum uniformity 0.4 and minimum Ra 60.
2.	Cat 2, Cat 3 and Cat 4:	S3 at Ra 60 or above
3.	Cat 2 and Cat 3.	S2 (S3 Ra>60)
4.	Cat 3:	S2 or S3 depending on crime stats
5.	Cat 4:	S4, S3 or S2 depending on crime stats
6.	As main carriageway and surround ratio for Cat 1a, 1, 2 and 4	
7.	This is covered under the lighting class for the road (All Cats)	
8.	Most commonly work to S2 when not using old BS (All Cats)	

3.2.7 Ranking of factors considered in specifying lighting including light intrusion and energy consumption

Many factors can be considered when specifying the lighting for a particular scheme. Four factors were considered to be of prime importance, these were safety, security, energy consumption and intrusive or stray light. Respondents were asked to rank their priority for each factor, giving a rank of 4 for the most important and a rank of 1 for the least important. However, some respondents ranked some factors equally and some found it difficult to separate as they were all regarded as equally important. For this reason the values reported were averaged in the analysis. The results are summarised in Table 3.7.

Table 3.7 Priority of safety, security, energy and light intrusion

	Safety	Security	Energy consumption	Light intrusion	Number of responses	Notes*
Cat 1	3.1	1.6	2.8	2.4	9*	10 for "safety"
Cat 2	3.1	2.1	3.0	2.3	20	
Cat 3a	3.1	2.1	2.9	2.3	21	
Cat 3b	3.3	2.5	2.6	2.3	21	
Cat 4a	3.3	2.5	2.5	2.4	21	
Cat 4b	3.2	2.9	2.4	2.3	21	

Key

Rank	Highest	2nd	3rd	Lowest

The table shows that, on average, safety is considered the highest priority for all road categories, although the variation in this result was the highest, due to some responses placing it as highest and others as lowest priority. On average, energy consumption is ranked the second most important, except on Category 4b (Link access) roads where security is ranked second. The priority of light intrusion is consistent across all road categories (average value of 2.3 to 2.4). As might be expected, security received the lowest average priority on Category 1 roads (Motorways).

3.2.8 Obtrusive light limitations for exterior lighting

Authorities were asked whether they try to take account of the guidance provided by the ILE on obtrusive light (ILE, 2000) when specifying lighting schemes.

The guidance was used by 71% of respondents. Those who do not use this document mentioned variously that each design is looked at individually or aesthetics of equipment takes precedence over strict lighting control in high district brightness areas (E4). Further comments from five respondents are given in Table 3.8. (Note that the GN01 environmental classification is embodied in BS5489, Table B4 for the selection of S-Classes for subsidiary roads.)

Table 3.8 Supplementary comments on policy for limitation of obtrusive light

Respondent	Environmental zone	Response
1	E1 & E2	Cut off/flat glass
	E3 & E4	Semi cut-off (see glossary in Appendix A)
2	E1	Very limited lighting to glare class 4-6
	E2	Split into two zones, E2a rural small villages, E2b rural large villages , different codes used, care taken with stray light
	E3	Light allowed to fall on house frontages to provide vertically illuminated surfaces. Glare Class 1-3 specified
	E4	Usually decorative equipment, aesthetics of equipment takes precedence over strict light control
3	E1 to E4	None at the moment - G classifications limits to be introduced (see glossary in Appendix A)
4	E1 to E4	Road Lantern specifications includes upward light output ratio (ULOR) not greater than 2.5%
5	E1 to E4	Each design is looked at individually. “Low Profile” lanterns are specified and if necessary “Flat Glass”. Light shields can be fitted where required

3.2.9 Lighting equipment

The types of policy in operation by the local authorities for specifying lighting equipment are given in Table 3.9, together with the percentages of the responding authorities operating each type of policy.

3.2.9.1 Lamp type

The table shows that 86% of respondents have a policy on the type of lamps specified for lighting schemes. 14% (3 respondents) did not have a policy on lamp type.

3.2.9.2 Time/traffic flow dependant dimming

Only 14% (three respondents) had a dimming policy and one of these had a policy not to dim because “*there is no cost benefit at present to justify the cost except in new developments where the developer pays*”.

3.2.9.3 Extinquishing lamps at certain times

Only 24% (five respondents) had a policy on part-night extinguishing. One respondent stated that their extinguishing is limited to a small number of high wattage lamps in a small number of areas, where every second lamp is extinguished. *“For lower wattages there is no cost benefit to installing the necessary equipment and no demonstrable appetite for widespread extinguishing.”* Note that this is generally considered to be poor practice, because of the averse effect on lighting uniformity.

Table 3.9 Types of policy in operation

Policy	Yes	No	Number of responses
Lamp type	18 (86%)	3 (14%)	21
Dimming	3 (14%)	18 (86%)	21
Extinquishing	5 (24%)	16 (76%)	21
Central monitoring	4 (19%)	17 (81%)	21
Central remote	4 (19%)	17 (81%)	21
Passive safety	6 (29%)	15 (71%)	21

Key

Over 50%	(yellow)
Under 50%	(pink)

3.2.9.4 Centralised remote control and monitoring.

Only 19% (four respondents) reported a policy on central control and monitoring. One respondent stated that their policy is not to have centralised monitoring or central remote control, *"as presently there is no cost benefit to installing the necessary equipment".*

3.2.9.5 Passive safety

Six respondents (29%) reported a passive safety policy. One respondent stated that their policy is not to purchase specialised lighting columns as no cost benefit can be demonstrated for council roads. The number of injuries arising from accidents involving lighting columns was stated to be very low. A recent TRL analysis of the national STATS19 injury accident data for 2001 to 2005 (Crabb *et al*, 2008) found that 1.5% of all injury accidents in this period involved impact with a lighting column, while 8.5% involved impact with other off-carriageway objects.

3.2.9.6 General comments

Some further general comments from respondents are given in Table 3.10. Five respondents mentioned Philips' Cosmopolis system by name (see notes 3, 4, 5, 11 and 15 in this table). The Cosmopolis system is a recent Philips development incorporating both high pressure sodium and ceramic metal halide lamps with luminaires and control gear optimised for the lamps. The lamps are both smaller and of lower wattage than the lamps they are designed to replace, but have similar light output.

Table 3.10 General comments on types of policy in operation

Note	Comment
1	Lamp type - Min CRI of 23; extinguishing lamps; PECU 70 lux rating.
2	To increase the use of HPS lighting within existing budgets, balancing the benefits of improved lighting against additional energy costs.
3	Standard lamp types are 35W and 70W CDM 70W 100W AND 150W SON. Lanterns are generally shallow bowl but can vary. Electronic gear on trial but not generally specified yet - too expensive. No dimming. Trials also of Cosmopolis and LED sources
4	"White" light specified for residential and city centre areas, typically 36/55w PLL and 45/65w Cosmo: Part night lighting policy on residential streets, 33,000 lights currently
5	Currently 150watt, 100watt, 70watt, 50 watt Sont+ 60 and 70 watt Cosmopolis, Phillips Iridium and Urbis ZX range, Harvard Electronic Leafnut Control Gear, Leafnode/Branchnode (currently being installed), fully dimmable. (Staff training taking place)
6	All lamps shall have a colour temperature equal to or better than 1950K and a colour rendering index (R_a*) equal to or greater than 25. The IP rating for all luminaires shall be a minimum of IP65.
7	Within the latest Road Lighting Policy (draft) guidance is given with regards where certain lamp types and luminaires should be used. Guidance on the type and switching ratios of photocells are also provided. Despite the absence of specific policies, references are made within the proposed Road Lighting Policy (draft) to dimming, remote monitoring and passive safety.
8	Various HPS 70, 100, 150, 250 watt
9	Lamp type CDO (ceramic metal halide), PLL (compact fluorescent), HPS. Lantern: shallow bowl/curved tempered glass. Electronic gear, non-dimmable. Lamp wattage 150/55/36/70
10	Equipment specifications available on request
11	Lamp type policy is "white" light, concentrating on Cosmopolis. We are just about to start some trials with remote monitoring systems, waiting for equipment to arrive. The use of such systems will be written into the new lighting policy. Passive safety columns are being specified where necessary, but not yet detailed in specification.
12	All road lighting lamps specified to indicate colour index, colour temperature, initial lamp lumens, lumen maintenance at *x* hours, life expectancy at *y* hours and lamp circuit watts (*x* and *y* varying depending on lamp type source).
13	New lanterns installed are compatible to enable option of remote monitoring. Some locations are currently trialling the technology including the facility to dim in certain locations i.e. park-and-ride car parks.
14	All new installations and conversions lamps shall be high-pressure sodium unless otherwise agreed.
15	High pressure sodium (SON/T +), Cosmopolis (CPO), Ceramic metal halide (CDM).

3.2.10 Types of lamps and luminaires specified (carriageway)

The types of lamps and luminaires specified by authorities for various categories of carriageway are given in Table 3.11 and Table 3.12 respectively.

The results in Table 3.11 show that HPS (SON) is the most frequently specified in all categories with at least 71% of respondents specifying this type of lamp. CFL lamps are specified by a few respondents on link roads (Cat 4a) and Local access Roads (Cat 4b). One respondent stated that for a secondary distributor road (Cat 3b) HPS or any lamp having R_a of 60 or above and for local access road (Cat 4b) any lamp having R_a 60 or above. Cosmopolis lighting was mentioned by two respondents.

Table 3.11 Type of lamp specified (carriageway)

Lamp	HPS SON	MH or CMH	CFL	Other	Number of responses
Cat 1	**6 (86%)**	**0**	**0**	**1**	**7**
Cat 2	**17 (85%)**	**1**	**0**	**2**	**20**
Cat 3a	**18 (86%)**	**1**	**0**	**2**	**21**
Cat 3b	**18 (86%)**	**1**	**0**	**2**	**21**
Cat 4a	**15 (75%)**	**1**	**2**	**2**	**20**
Cat 4b	**15 (71%)**	**0**	**3**	**2**	**20**

Key

Rank	Highest	2^{nd}	3rd	Lowest

Other comments relating to Table 3.11

1. Cat 2, 3a, 3b, 4a, 4b Cosmopolis also specified
2. Cat 2, 3a, 3b, 4a, 4b Cosmopolis CPO-TW
3. Cat 3a, 3b, 4a, 4b SOX lighting on old schemes

To avoid excessive complication, luminaires were classified in one of four groups for the purposes of the questionnaire. These categories were "deep bowl", "shallow bowl", "flat glass" and "other". These descriptions were designed to provide an approximate measure of the degree of light control provided. In practice the light control also depends on several other factors including the size and position of the lamp and the reflector design. The "other" category includes types such as decorative luminaires selected for their aesthetic appearance. These may also provide good light control, depending on their design. Table 3.12 shows that "flat glass" are the most frequently specified on motorways (4 respondents) and shallow glass are the most frequently specified (at least 70%) on all other categories of road. Flat glass are the second most frequently specified on strategic routes (Cat 2) and main distributors (Cat 3a). Flat glass and deep bowl are equally as frequently specified on secondary distributors (Cat 3b). Deep bowls are second most frequently specified for link roads (Cat 4a) and local access roads (Cat 4b).

It is clear that "deep bowl" luminaires, used widely in the past, particularly with large low-pressure sodium lamps and offering relatively poor control of light distribution are now relatively infrequently specified for any road categories.

Table 3.12 Type of luminaire specified (Carriageway)

Luminaire type	Shallow	Deep	Flat	Other	Number of responses
Cat 1	**1**	**0**	**4 (67%)**	**1**	**6**
Cat 2	**14 (70%)**	**1**	**5**	**0**	**20**
Cat 3a	**15 (71%)**	**1**	**5**	**0**	**21**
Cat 3b	**17 (81%)**	**2**	**2**	**0**	**21**
Cat 4a	**17 (85%)**	**3**	**0**	**0**	**20**
Cat 4b	**17 (81%)**	**4**	**0**	**0**	**21**

Key

Rank	Highest	2^{nd}	3rd	Lowest

Other comments relating to Table 3.12.

1. Cat 2, 3a, 3b, 4a, 4b Can vary owing to the nature of the county council's environment
2. Cat 2, 4a, 4b (shallow bowl or flat glass), Cat 3a 3b (shallow bowl or flat glass, or decorative)
3. Cat 2, 3a, 3b, 4a, 4b Flat glass some locations
4. Cat 3a, 3b, 4a, 4b can also be flat glass
5. Cat 2, 3a, 3b, 4a, 4b The choice of bowl type depends on design and road location

3.2.11 Types of lamps and luminaires specified (footway)

The types of lamps and luminaires specified by the authorities for various categories of footway are given in Table 3.13.and Table 3.14 respectively.

Table 3.13 shows that Metal Halide or Ceramic Metal Halide are the most frequently specified on prestige walking zones (Cat 1a) and HPS (SON) are the most frequently specified on all other categories. CFL are second most frequently specified for link footways and local access footways (Cats 3 and 4). Cosmopolis was mentioned as specified by 2 respondents.

Table 3.13 Type of lamp specified (Footway)

Lamp	HPS (SON)	MH or CMH	"white" SON	CFL	Other	Number of responses
Cat 1a	**4**	**9 (45%)**	**2**	**0**	**5**	**20**
Cat 1	**8 (40%)**	**5**	**2**	**0**	**5**	**20**
Cat 2	**9 (45%)**	**2**	**1**	**3**	**5**	**20**
Cat 3	**8 (42%)**	**1**	**1**	**5**	**4**	**19**
Cat 4	**8 (42%)**	**1**	**1**	**5**	**4**	**19**

Key

Rank	Highest	2nd	3rd	4th	Lowest

Other comments relating to Table 3.13.

1. Cat 1a, 1, 2, 3, 4 Light source types vary depending on brief
2. Cat 1a, 1, 2, 3, 4 . Cosmopolis CPO-TW
3. Cat 1a, 1, 2, 3, 4 Any lamp having Ra 60 or greater
4. Some ceramic metal halide lamps Cat 3 & 4 or decorative. Some ceramic metal halide lamps.
5. Cat 1a, 1, 2, 3, 4 . CosmoPolis
6. Cat 1a &1 Moving to CDM "white" light
7. Cat 3 Son(HPS) and CFL subject to width

Table 3.14 shows that the most frequently specified luminaire type for footways is "shallow bowl", with very few "flat", for all categories. It is expected that the "other" category includes luminaires of the "decorative" type chosen primarily for aesthetic appearance. (This characteristic does not necessarily impair optical performance.)

Table 3.14 Type of luminaire specified (Footway)

Luminaire type	Shallow	Deep	Flat	Other	Number of responses
Cat 1a	**12 (57%)**	**3**	**1**	**5**	**21**
Cat 1	**12 (57%)**	**3**	**1**	**5**	**21**
Cat 2	**14 (67%)**	**4**	**0**	**3**	**21**
Cat 3	**10 (48%)**	**8**	**0**	**3**	**21**
Cat 4	**12 (60%)**	**5**	**0**	**3**	**20**

Key

Rank	Highest	2nd	3rd	Lowest

Other comments relating to Table 3.14.

Cat 1a, 1 Contingency theory - it all depends on the circumstances

Cat 2, 3, 4 Linear footpath - post mount, Non-linear footpath - post top

Cat 1a, 1, 2, 3, 4 Luminaire types vary depending on brief

Cat 1a 1 Generally the lanterns are specialist treatment

Cat 1a, 1, 2 or flat glass, or decorative.

Cat 1a & 1 Decorative

Cat 1a & 1 Can also be heritage/modern deco, of various shapes and sizes.

Cat 1a, 1, 2, 3, 4 The choice of bowl type depends on design and road location

3.2.12 Maintenance

Authorities were asked to provide information on the maintenance regimes specified for their lighting schemes. The intervals reported between cleaning luminaires are given in Table 3.15. The results show that 36 months is the most common interval between cleaning with 38% of respondents specifying this time interval. It is also evident that there is wide range which goes from 'no cycle' all the way down to "every 12 months". One respondent (see comment 1) gave cleaning intervals for different types of lamp which varied from 24 months to 48 months. Comment 2 notes that less cleaning is required with luminaires of modern design and cleaner air than in the past.

Table 3.15 Number of councils with given time interval between cleaning

Months	12	18 & 24	24	36	48	72	Other	Responses
Number	2	1	2	8 (38%)	2	1	5	21

Other comments relating to Table 3.15

1. SOX 24 months; CDM/T 24 months; HPS 36 months; SON/PIA 48 months.
2. We only clean at lamp change. With modern luminaires and cleaner air than say 40 years ago, only in a few locations is supplementary cleaning required.
3. Lights to only be cleaned at time of other operations.
4. Cleaning now carried out with bulk lamp change at various change frequencies determined by manufacturers recommendations.
5. No cycle, at lamp change.

3.2.13 Lamp changes

Respondents were asked when they changed their lamps. The results showed that 14 respondents (67%) changed the lamps in batches and the remaining 33% burnt to extinction. Burning to extinction may lead to more lights not operating on average as failure is unpredictable. Lamps operated beyond their rated life may also emit less light than required to comply the specified "minimum maintained" lighting level, due to lumen depreciation (see Glossary, Appendix A). Lamp change policy is discussed more fully in "Well Lit Highways" (UKLB, 2004).

3.2.14 Meeting current light standards

Respondents were asked how they ensured that current lighting standards are met. A total of fourteen (67%) had a set frequency of lamp changes and three respondents specified routine measurement of the light output. One of these specified both procedures. The respondents who did not specify these methods mentioned "night-scouting", "meeting the BVPI 3 day repair", "standard only met for new installations" and "with the removal of 'bulk lamp change' no method currently exists to ensure lighting standards are met".

3.2.15 Existing policy

Respondents were asked if the existing policy for new or replacement schemes uses a current guidance document when selecting the appropriate lighting class. The responses are given in Table 3.16. The table shows that most policies specify BS5489 in some form, with a small number specifying CEN TR13201-1. Only 10% of policies do not specify the use of these documents.

Table 3.16 Guidance documents specified by respondent council's policies.

BS5489-1, Annex B	CEN TR 13201-1	Modified	None	Number of responses
14 (67%)	3 (14%)	2	2	21

Notes on Table 3.16

1. One respondent used their own Council guidance notes on lighting standards.
2. One respondent reported that their policy states that all new schemes will be in accordance with BS5489.
3. One respondent stated that their own Council lighting strategy is based on CEN TR 13201 but has different selection criteria.

3.2.16 Use of reduced levels when using S classes (see Section 2.2.2)

The respondents were asked, *"If BS 5489-1 Annex B is specified when selecting S classes, is use made of the possibility to reduce levels when white light is used?"*

Fourteen respondents (70%) stated that they do make use of reducing levels when "white" light is specified. Six respondents (30%) answered 'No' but two of these stated that reduced levels are 'Only used when site conditions prevent required standards from being met' and 'Trials are underway using S class in appropriate conditions' respectively

The respondents who did not reduce levels when "white" light is specified were asked if they felt that it would be good to have a guide which advised on the "*maximum light level required and given by current lighting technologies which may reduce over-specifying and ultimately save energy and cost*". All of those (3 respondents) who answered the question thought that it would be a good idea, with one respondent noting that over-lighting can be a problem in rural areas, where good quality and uniformity is much more important than high levels.

3.2.17 Electronic control gear

Respondents were asked if their current policy for new or replacement schemes specifies the use of electronic control gear for discharge lamps.

Thirteen respondents (62%) have such a policy and seven respondents (33%) did not. One respondent stated that electronic control gear was only specified in new housing developments. One respondent, who did not specify electronic gear, was working to amend the policy so that electronic gear could be specified and another respondent's authority is monitoring the technology.

3.2.18 General comments from respondents in addition to questionnaire responses

1. *Most of our design is in built-up urban areas where geographical layout supersedes design spacings. However we do work to S2 most commonly where we are not using the old BS. We have not dealt with any conflict areas since this was introduced. There are no PFI in Scotland and latest standards are driven by PFI criteria.*
2. *I spent ages deliberating over that question! (Question 6). I tried to rank them in order of importance but they are all equally important in an inner city urban area. Prioritisation has to be decided on a road by road basis taking account of accident/crime statistics and police/resident input and cannot be categorised according to road status.*
3. *Even though our policy document is rather dated and compact, we do specify quite rigid requirements with reference to equipment types as part of our Section 38/278 process, however, from a design point of view, we only stipulate that designs must be in accordance with the current BSEN requirements for the category of highway being lit.*
4. *I had a few problems in completing the questionnaire for the following reasons:*
    - *Footways are generally lit using the same lighting units that are installed to light the main carriageway (in the interest of reducing energy and capital costs), with only separate footways lit to a specific class.*
    - *Lighting for conservation areas, town centres and high crime areas etc is often non-standard.*

3.3 Current application of lighting standards in the UK

The principal objective of the consultation exercise was to determine how well the existing standards and guidance are being used in specifications for new and replacement lighting. The following tables examine the evidence for possible over-lighting compared with the range specified in the standard. The analysis was not able to take account of any special conditions which might give rise to a high level.

Table 3.17 indicates that over-lighting does not appear to be a general problem for carriageway links. One respondent indicated the use of class ME1 in Categories 2, 3a, 3b and 4a (coded green). This may represent over-lighting, particularly for the lower carriageway categories, unless this is required for some unknown reason. (Both ME and S classes are given. S1 is approximately equivalent to ME3; see Table 2.1).

Table 3.18 shows no evidence for over-lighting in conflict areas. (Both CE and S classes are given. S1 is approximately equivalent to CE3; see Table 2.1).

Table 3.19 indicates no significant over-lighting for footways. One northern English county respondent noted that lighting for conservation areas, town centres and high crime areas etc is often non-standard.

Table 3.17 Possible over-lighting (Carriageway links)

	ME1	ME2	ME3a	ME3b	ME4b	S1	S2	S3	NA
Cat 1	5	1	0	0	0	0	0	0	15
Cat 2	1	12	3	0	0	0	1	1	2
Cat 3a	1	8	6	1	0	0	1	1	1
Cat 3b	1	4	5	3	1	0	2	2	1
Cat 4a	1	0	1	1	6	4	2	2	2
Cat 4b	0	0	0	1	3	3	5	3	1

Note to Table 3.17, Table 3.18 and Table 3.19: the light shading indicates the approximate expected range according to BS5489:2003

Table 3.18 Possible over-lighting (Conflict areas)

	CE0	CE1	CE2	CE3	CE4	CE5	S1	NA
Cat 1	3	1	0	0	0	0	0	14
Cat 2	1	10	6	0	0	0	0	4
Cat 3a	0	10	6	2	0	0	0	3
Cat 3b	0	5	7	2	2	0	0	3
Cat 4a	0	1	1	9	0	2	1	4
Cat 4b	0	1	0	3	5	2	3	5

Table 3.19 Possible over-lighting (Footway)

	CE1	CE2	CE3	S1	S2	S3	S4	S5	S6
Cat 1a	8	2	1	3	0	2	0	0	0
Cat 1	3	6	1	5	0	0	1	0	0
Cat 2	0	0	3	3	2	5	3	1	0
Cat 3	0	0	0	1	3	7	5	3	0
Cat 4	0	0	0	0	3	4	8	2	1

Note to Table 3.19: The CE1 class is advised by BS5489-1, Table B5 for city and town centres, for all traffic flows, in medium (E3) and high (E4) district-brightness areas. CE1 is also advised for E4 areas with normal traffic flows but not E3 areas with normal traffic flows.

3.4 Summary

- No policies which would result in significant over-light were reported
- All of the respondents' specifications use current standards and professional guidelines. BS5489:2003 and BSEN13201:2003 were used by all except one who used 'current standards and professional guidelines'
- B5489-1 Annex B (79%) was more frequently specified than CEN/TR13201-1 (21%) for selecting the lighting class
- Safety was the most important consideration in specifying lighting on all roads
- Energy consumption was generally second most important in specifying lighting
- Very few of the authorities have dimming policies
- LPS lamps are no longer being specified by any of the respondent authorities. HPS (SON) were the most frequently specified lamps on all roads
- The most frequently specified type of luminaire is "shallow bowl" on all roads and footways except motorways, where more sharply cut-off "flat glass" luminaires are specified
- The most frequently specified luminaire cleaning interval was 36 months. This would coincide with lamp changes for some lamps. The range of cleaning intervals was from 12 months to 'at lamp change', which could be 4 years for current HPS and some CMH lamps.
- Batch changing of lamps was twice as frequently specified as burning to extinction
- Ranking safety, security, energy consumption and light intrusion was considered difficult in inner city urban areas
- Philips Cosmopolis system was specifically mentioned by 5 of the 22 respondents
- Some respondents have concerns that the technology of more efficient lighting is relatively new and undergoing rapid development and that any cost advantage has yet to be proved. However, trials are underway in a number of authorities.
- There was no information on the reliability of new technology.

3.5 Discussion

The responses to the consultation reveal that the authorities seem to be generally specifying lighting within the bounds of the current standards. In most cases the highest lighting class specified for each class of road was within the range expected by BS5489. There were a few exceptions. One authority reported the specification of class ME1 on all traffic route road categories down to 4a, which would normally be lit to much lower classes. No such anomalies were apparent for conflict area or footway specifications. The reported precedences of safety, security, energy consumption and light intrusion were much as might be expected, with "safety" being given the highest rank on all categories of road and "energy consumption" being in second place for all categories except the lowest (Cat 4), where "security" took second place. Minimisation of "light intrusion" received a consistently low ranking.

The majority of authorities noted the use of the ILE document GN01 on control of obtrusive light (this is embodied in BS5489 for subsidiary roads lit using the S classes). There were some notes about light distribution, including, "light is allowed to fall on house frontages", and in the least-restricted environmental zone (E4), "aesthetics of equipment takes precedence over strict light control". There were no notes about the avoidance of spill light into upper windows, which can be a particular problem with poorly controlled luminaires, particularly if mounted too high.

Most of the respondent authorities have policies on lamp type but few have policies on dimming or the other topics listed in Table 3.9 (extinguishing, central monitoring, central control and passively safe columns). There was a range of other comments, listed in Table 3.10, which demonstrated considerable interest in Philips' "Cosmopolis" system and several trials of white light, dimming or central control. Some respondents considered electronic control gear to be too expensive at present.

None of the respondent authorities are specifying low-pressure sodium lamps. These are being replaced generally with high-pressure discharge lamps when replacement of luminaires is necessary. The most commonly specified lamp for all categories of road is high-pressure sodium, with some mention of metal halide or compact fluorescent.

Shallow bowl luminaires were the most commonly specified except for motorways, where "flat glass" was most common.

4 Costs of lighting systems

In order to determine the relative costs of various lighting options, including new technologies, several companies were approached who were able to provide indicative unit costs for their systems. Some of these have been used to develop a whole-life-cost comparison of four different types of lighting system.

A summary of the collected costs is provided below, broken down into the cost of the lamp units, housings and luminaires and the control gear (including the lamp ballast). Quotes were obtained from a number of suppliers, contractors and installers in order to provide an accurate representation of the costs. Further details of the range of costs are given in Appendix B.

4.1 Cost of lamps, lamp housings and luminaires

Estimates of the cost of lamp units of a range of wattages were obtained from major suppliers. These are summarised in Table 4.1 for typical lamps.

Table 4.1 Typical lamp costs

Lamp type	Typical cost
HPS (SON) (100W)	£8
"Conventional" CMH (100W)	£20
Cosmopolis (CMH) (90W)	£27
CFL (36W)	£4.50
LPS (SOX) (90W)	£20

Average costs of luminaires ranged from around £107 for a 70W luminaire to £240 for a 400W luminaire. More details of the costs compiled are given in Appendix B.

4.2 Cost of control gear

Table 4.2 provides a summary of the cost of different types of control equipment. Table B3 in Appendix B gives more detail.

The cost of electronic dimming systems was investigated. Some suppliers' claims would suggest that their systems could be expected to save up to as much as 50 percent or more of existing energy use when implemented as a replacement for conventional lighting installations using inductive ballasts. TRL have been unable to source actual calculations from the suppliers to support these claims. Estimation based on existing knowledge suggests much lower figures in a practical situation.

Previous studies carried out by TRL, including a full-scale trial of a lamp dimming system in 2004, estimated that the maximum savings achievable via electronic dimming systems (including 'compensation' dimming to reduce the levels when lamps are new) was around 22% (see Appendix C) (Crabb *et al*, 2005). This estimate is similar to that provided by one county council, for systems in operation on their network (see Section 4.5.1). A summary of how their estimated savings were derived is provided in Table C2 in Appendix C. (Note that this is a system using dual tapped electromagnetic ballasts and not electronic control gear).

Table 4.3 shows typical quoted costs associated with the components required to implement a system using suitable electronic ballasts and dimming electronics. Whole-life cost comparisons of four example systems are discussed in Section 4.3.

Table 4.2 Typical control gear costs

Equipment type	Power (W)	Average cost (£)
Electronic ballasts	50 or 70	26
	100	39
	150	40
	250	53
	400	63
Inductive ballasts	All	23
PECU*	NA	10
Isolators	NA	13
Ignitors	NA	6

*Photo-electric Control Units

Table 4.3 Typical costs of components required for dimming

Description	Average cost (£)
Additional electronics required for each individual lamp	155
Controller (one unit serves up to 255 lamps)	500
Master controller	500
Enabled Ballasts	70

4.3 Energy and whole-life cost comparison of "conventional" and "advanced" systems

Using information on energy consumption and costs obtained in this study, illustrative energy consumption and whole-life costs, over a typical 30-year design life, have been calculated for four different systems spanning the range of types available for street lighting. All four estimates have been based on a 10p/kWh electricity price, which is a little higher than most authorities are currently paying. Three of the systems use a 150W HPS lamp and one a 140W Cosmopolis (The Philips system described in Section 3.2.9.6 mentioned by name by several respondents in the survey). The four systems are:

- conventional HPS system with inductive ballasts,
- an HPS system using electronic control gear without dimming,
- a Cosmopolis system with electronic gear without dimming and
- an HPS system using electronic control gear with dimming and remote control and monitoring

The part-night dimming scheme is based on dimming between midnight and 5:30am to two-thirds power (approximately 50% output). This is based on practice reported by an authority in the survey.

A number of simplifying assumptions were made in order to provide these estimates;

- The lamp change interval was taken as four years for the HPS lamp and three years for the Cosmopolis lamps.
- The comparison assumes similar numbers of lamps in each scheme.
- Ballast lifetime for electromagnetic gear was taken to be 15 years. For electronic control gear except Cosmopolis a life of 10 years was used, based on information from various sources. For Cosmopolis electronic gear a typical service life of 60,000 hours is claimed. This has been approximated to 15 years.
- The "part-night dimming with central control" option includes costs for extra equipment, such as lamp control units.
- Costs for a 10m column are included, but there is no allowance for installation or labour costs.

Table 4.4 and Figure 4.1 compare the annual energy consumption and energy cost per lamp respectively using the above assumptions.

Table 4.4 Comparison of annual energy costs at 10p/unit

	Consumption lit (W) (1)	Consumption unlit (W)(2)	Annual hours on	Annual hours off	Consumption (annual, kWh)	Cost (£) at 10 pence/ kWh	Saving compared with conventional (4)
Conventional	172	0.25	4380	4380	754.46	75.45	0.0%
Electronic	164	0.25	4380	4380	719.42	71.94	4.6%
Cosmopolis	157	0.25	4380	4380	688.76	68.88	8.7%
Part-night dimming (3)	141	5	4380	4380	639.85	63.98	15.2%

Notes to Table 4.4.

1. The "consumption lit" figures were taken from ELEXON (2007).
2. The figures for "consumption unlit", for the first three systems, were taken as the figure for "Electronic photo-cell (latching relay)" given in the same document.
3. For the part-night dimming system a figure has been estimated for the "consumption unlit". ELEXON (2007) provides a figure of 3W for an "Electronic photo-cell time switch". TRL measured 7W for the programmable electronic 256 dimming-step electronic gear and powerline controller used in the NumeLiTe trial (Section 2.6.1). Manufacturers seem reluctant to provide information on this "standby" power. It is important to know as it offsets to some extent the potential savings during burning hours.
4. The percentage saving is not affected by changes in the energy cost. Further energy could be saved if it was possible to compensate for lumen depreciation by dimming new lamps to the end of life output and progressively adjusting this dimming as the lamp aged. This approach would need dimming gear with a large number of fine steps to be effective.

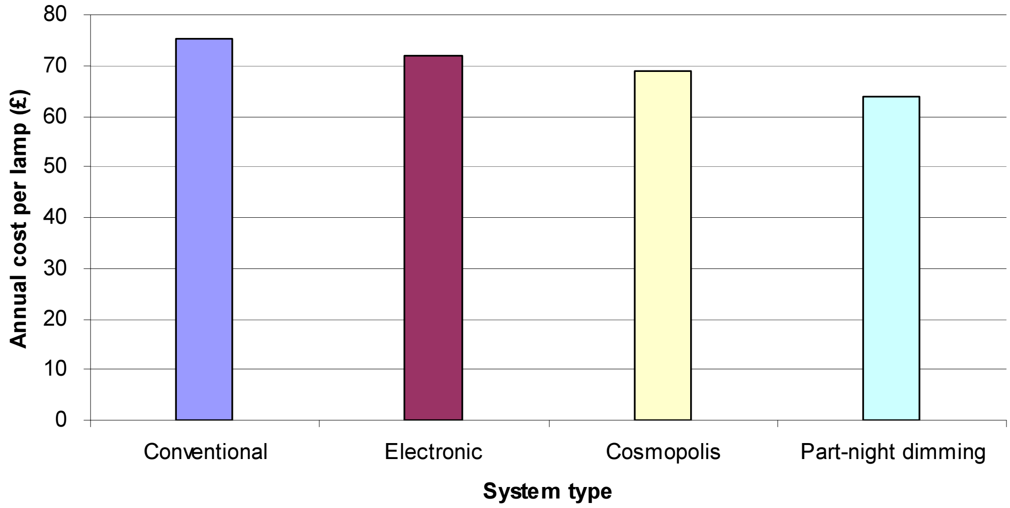

Figure 4.1 Energy cost comparison

It is seen that the annual energy consumption and cost of energy are reduced by the electronic systems compared with the conventional system. The savings are not, however, large. The part-night dimming system has the greatest energy saving potential at about 15%. A Cosmopolis system with part-night dimming could show a further saving. As already mentioned part-night dimming with dimming to compensate for lumen depreciation could achieve in the region of 22% saving. If an installation permitted wider column spacing then further savings could be made. These comparisons show the potential energy savings in comparison with similarly efficient luminaires. Further savings are possible if comparison is to be made between an existing system which is very inefficient due to poor light control and a modern system.

The 30-year whole-life-costs (WLC) of the four systems are compared in Table 4.5 for a 10p/kWh energy cost. The calculations use the discount rate of 3.5% currently specified by HM Treasury for transport infrastructure, to estimate the present value of future expenditure. This factor takes account of future interest and inflation rates, but cannot take account of costs that rise faster than inflation. To accommodate energy prices rising faster than inflation the calculation has been repeated for an energy cost of 20p/kWh. The results are shown in Table 4.6.

The totals in Table 4.5 are compared graphically in Figure 4.2, and the breakdown into energy and component costs is shown graphically in Figure 4.3. It is seen that the energy cost saving at current prices is exceeded by the increased hardware costs of the more expensive systems at current energy costs. This results in a higher WLC for the most energy saving systems. However, as shown in Table 4.6, as the energy cost rises the more energy-saving systems begin to show an advantage.

It appears from this that, at current energy costs, advanced lighting systems are likely to generate a similar whole-life-cost, with some differences between systems, to conventional systems. If the cost of energy rises the initially more expensive energy-saving systems will show progressively greater financial benefit over their life.

Table 4.5 Simplified 30-year whole life cost comparison at 10p/kWh (discount rate 3.5%)

	Consumption (annual, kWh)	Initial costs (£)	Annual cost at 10 pence/kWh (£)	Energy costs (£)	Replacement lamps (£), (Life years)	Ignitors (£), (Life years)	Luminaires (£)	Ballasts (£)	Total (£)	Saving relative to conventional
Conventional	755	441	75	1,388	37 (4)	4 (15)	106 (15)	13 (15)	1,989	0.0%
Electronic	719	450	72	1,323	37 (4)	-	106 (15)	38 (10)	1,954	1.7%
Cosmopolis White	689	522	69	1,267	144 (3)	-	121 (15)	52 (15)	2,106	-5.9%
Part-night dimming with central control	640	663	64	1,177	37 (4)	-	106 (15)	62 (10)	2,045	-2.8%

Table 4.6 Simplified 30-year whole life cost comparison at 20p/kWh (discount rate 3.5%)

	Consumption (annual, kWh)	Initial costs (£)	Annual cost at 20 pence/kWh (£)	Energy costs (£)	Replacement lamps (£), (Life years)	Ignitors (£), (Life years)	Luminaires (£)	Ballasts (£)	Total (£)	Saving relative to conventional
Conventional	755	441	150	2,775	37 (4)	4 (15)	106 (15)	13 (15)	3,376	0.0%
Electronic	719	450	144	2,646	37 (4)	-	106 (15)	38 (10)	3,277	2.9%
Cosmopolis White	689	522	138	2,534	144 (3)	-	121 (15)	52 (15)	3,373	0.1%
Part-night dimming with central control	640	663	128	2,354	37 (4)	-	106 (15)	62 (10)	3,222	4.6%

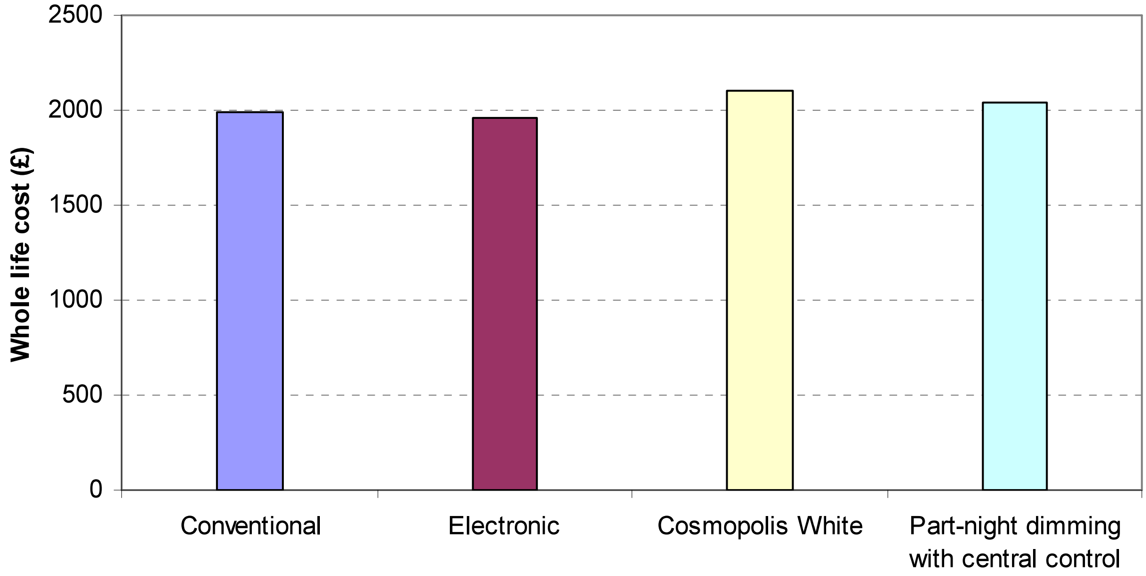

Figure 4.2 Comparison of 30 year whole-life costs at 10p/kWh and 3.5% discount rate

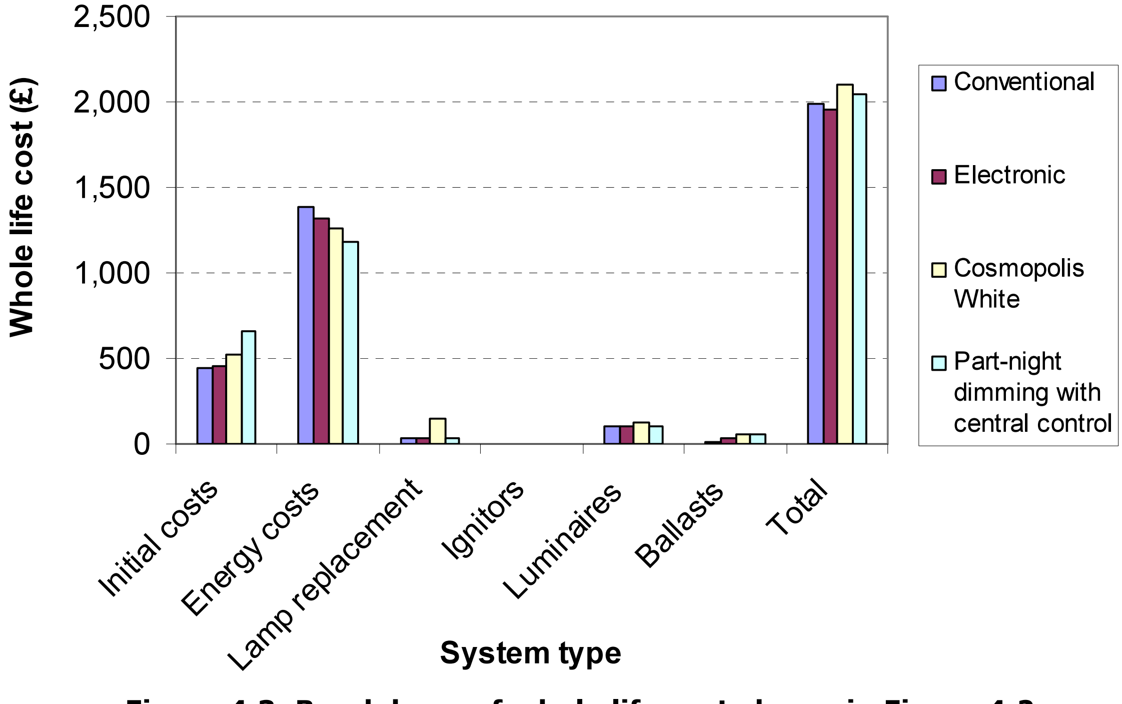

Figure 4.3 Breakdown of whole life cost shown in Figure 4.2

4.4 Other control gear factors affecting energy consumption and cost

Potential benefits that accrue from the use of electronic control gear, are

- a high reactive power factor, which minimises energy losses in transmission and
- improvements in the life and stability of lamps.

The high power factor is less likely to degrade, as has been observed in electromagnetic systems due to the aging or failure of the capacitors used for power factor correction. However, high frequency electronic systems can produce harmonic distortion, which is a separate source of power factor reduction. This problem can only be mitigated by the inclusion of effective filtering in the equipment, as is believed to be the case with equipment provided for street lighting use.

Care should also be taken to assess the power consumption in the "off" or "standby" condition and include this in calculations, as has been done here, as this detracts from any energy savings.

4.5 Dimming case histories reported in the consultation

A county in southern England is currently trialling remote monitoring including the facility to dim in certain locations i.e. park-and ride-car parks. Another county in the north of England, which does not have a dimming policy, is currently installing a fully dimmable system and staff training is taking place. From this brief analysis it appears that cost is an important factor, however trials are under way using the technology. Two subsequent responses regarding costs are given as Case Study 1 and Case Study 2.

4.5.1 Cost savings. Dimming case study 1

This respondent reported that his authority has a number of luminaires (150w, 250w and 400w – assumed HPS) which can be dimmed using dual-tapped conventional (electromagnetic) ballasts. Measurements demonstrated that the dimmed energy consumption was 50% (this would correspond with substantially less than 50% light output). Dimming is from 12 midnight until dawn, or 6am, whichever is soonest.

Total annual operating hours are estimated as 4155 (Note: this information is available in ELEXON, 2007) so the dimming period is about 1919 hours per annum. The calculated energy saving due to dimming is about 22%.

4.5.2 Cost savings. Dimming case study 2

This respondent reported that dimming was currently used in three park-and-ride car-parks but was not able to provide any figures for cost savings. However, the respondent expected that savings would be well under the 40% figure advertised by some equipment suppliers. A number of reasons were listed:

- *The majority of lights owned by a Lighting Authority such as us will be on estate roads and in villages. These units will mostly be of a low wattage and therefore may not be suitable for dimming as you will already be lighting at a low level of illumination*
- *Even if you do dim the above, this would only be for part of the hours of darkness*
- *The cost of achieving dimming on the low wattage lamps is highly likely to swallow up any savings for years to come due to new control gear capable of dimming being required*
- *As yet remote control systems are still in the development stage and no one can be sure how much the annual running cost for these systems will be. At present we are using the a system to control our dimming lanterns, BUT at present we are not*

paying for the use of the system, depending on the eventual costs that the provider decide that need to charge, will play a big part in how financially attractive their system is.

This respondent considered that switching lights off for a part of the night is likely to be more financially attractive than dimming, but politically difficult.

4.6 Discussion

The review of lighting equipment costs provides some insight into the relative costs of a range of equipment types. While the review is restricted to hardware costs and energy consumption, it is clear that, with the assumptions made, there is little difference in whole-life-cost (WLC) of the four systems compared. A saving in energy is made possible by the more advanced schemes, but the cost saving associated with this is balanced by the current higher cost of the equipment required. It should, however be noted that the WLC model used is simple and does not account for cost rises ahead of inflation of any of the elements. If the cost of energy rises steeply then the schemes using the least energy will generate lower whole-life-costs.

Savings in energy consumption due to the use of electronic control gear and/or part-night dimming depend on the base system used for comparison. The largest energy savings are likely to accrue from the replacement of inefficient with efficient luminaires. Comparison of a part night dimming system with the same system undimmed is likely to result in savings of 20% to 25%. These savings are also dependent on the application of a charging mechanism which takes account of the lower consumption. Care should be taken to assess the power consumption in the "off" or "standby" condition and include this in calculations, as this detracts from any energy savings. Other potential savings arising from the use of electronic gear are a high power factor, which minimises losses in transmission and improvements in the life and stability of lamps. The high power factor is less likely to degrade as has been observed in electromagnetic systems as a result of the aging or failure of the capacitors used for power factor correction in these systems.

The whole-life costing exercise carried out for this project shows no serious long-term financial impediment to specifying an "advanced" lighting system in comparison with a conventional system. The comparison, based on current costs, shows that over a typical 30-year life the higher capital cost of the more energy efficient systems is likely to be largely offset by the energy savings. This benefit is likely to increase if energy costs rise faster than inflation, as is likely. This conclusion is based on a whole life cost comparison per lighting point, so is independent of the size of the system. If the more advanced systems allow lower wattage lamps or a smaller number, the balance is moved further in favour of this type of system.

5 Conclusions and recommendations

This research has shown that the current standards and published guidance allow considerable flexibility in specifying lighting levels. The consultation has shown that current practice does not appear to deviate materially from the current British Standard (BSI, 2003b). However the review has shown that adoption of the extra flexibility in selecting lighting classes provided by CEN/TR 13201-1 could reduce the lighting class required in some cases.

- Local authorities should use this flexibility to set minimum lighting levels that will satisfy users without compromising safety, i.e. lighting should not be over-specified.
- Greater use should be made of CEN/TR 13201-1 which will result in better matching to requirements and allow savings in some areas.
- The impending revision of the British Standard should consider adopting more of the flexibility provided by CEN/TR 13201-1.
- Full use should be made of the guidance contained in the ILE guidance on variable lighting and its "Invest to Save" advice note.

The work carried out in this project has identified a number of approaches which if adopted by local authorities have the potential to reduce energy consumption and minimise whole-life costs, while maintaining or improving road safety. On the basis of these findings it is recommended that, when replacing lighting or installing new lighting, local authorities should:

- Replace low-pressure sodium lamps in inefficient luminaires with high-pressure sodium, ceramic metal halide or other small lamps in efficient luminaires providing good light control. This should allow the use of lower wattage lamps or wider column spacings.
- Select optically efficient luminaires which direct most of the light where it is needed. This will permit the use of the lowest wattage lamps which will satisfy the required lighting class. It will also reduce problems of light intrusion.
- Make use of the freedom to reduce the lighting class below that which would otherwise be specified when switching to "white" light. This is particularly important in residential streets, which are lit to a low level. This class reduction may permit the use of lower wattage lamps or greater column spacings. This reduction in class has been shown by research not to have a deleterious effect on visibility.
- Specify lamps of the minimum practical wattage, particularly if moving to "white" light. Replacement of inefficient with more efficient luminaires should allow this.
- Have a preference to select "white" light for residential and town centre areas and HPS for traffic routes.
- Avoid intrusive light spill, particularly in residential streets, by using appropriate luminaires and installation geometries.
- Specify electronic control gear, but look carefully at predicted life when calculating whole-life costs.
- Consider installing dimming where road use varies widely during lighting hours.
- Consider installing remote control and monitoring equipment.
- Carry out a whole-life-costing exercise to compare the costs of these options, along the lines of the comparisons presented in this report, before making the decision as to which equipment to install.

- Not assume that brighter or more lighting will automatically reduce levels of crime.

Acknowledgements

The work described in this report was carried out in the Technology Development and Quality Assurance Group of the Transport Research Laboratory. The authors are grateful to Alex Wright who carried out the technical review and auditing of this report.

References

BSI (1992). Road lighting (9 parts): BS 5489, British Standards Institution, London.

BSI (2003a). Road lighting. Parts 2, 3, 4. BS EN 13201. British Standards Institution, London.

BSI (2003b). Code of practice for the design of road lighting. Parts 1 and 2. BS 5489. British Standards Institution, London.

BSI (2004). Road lighting — Part 1: Selection of lighting classes. *BS Published Document* CEN/TR 13201-1. British Standards Institution, London.

CIE (1995). Recommendations for the lighting of roads for motor and pedestrian traffic. Technical Report CIE 115, Commission International d'Elairage, Vienna, Austria.

CIE (2000). Guide to the lighting of urban areas. *Technical Report* CIE 136, Commission International d'Elairage, Vienna, Austria.

Crabb GI and Steele D (2006). Are street lighting levels too high? *Paper in TRL Annual Research Review 2005*. Transport Research Laboratory, Crowthorne.

Crabb, GI, Beaumont, RJ, Steele, DP, Darley, P and Burtwell, MH (2005). Visual performance under CMH and HPS lighting systems (PPR043). *Published Project Report*. Transport Research Laboratory, Crowthorne.

Crabb, GI, Beaumont, RJ, Steele, DP, Darley, P and Burtwell, MH (2006). Visual performance under CMH and HPS street lighting at different power and dimming levels. (PPR069). *Published Project Report*. Transport Research Laboratory, Crowthorne.

Crabb GI, Crinson L, Beaumont R and Walter L (2008). The impact of street lighting on night-time road casualties (PPR318). *Published Project Report*. Transport Research Laboratory, Crowthorne.

ELEXON (2007). Unmetered supplies operational information. Version 3.0. 20 February 2007. ELEXON, the Balancing and Settlement Code Company for Great Britain, London.

Farrington, DP and Welsh, BC (2002). Effects of improved street lighting on crime: a systematic review. *Home Office Research Study* 251. Home Office, London.

Goodman T, Forbes A, Walkey H, Elholma M, Alferdinck K, Frieding A, Bodrogi P Varady G and Szalmas A (2007). Mesopic visual efficiency IV: a model with reference to night-time-driving and other applications (39, 365-392). *Lighting Research and Technology.*

ILE (2000). Guidance notes for the reduction of light pollution (GN01). *ILE Guidance Note*. Institution of Lighting Engineers, Rugby (Amended 2003, 2005).

ILE (2005). Code of practice for variable lighting levels (TR27). *ILE Technical Report*. Institution of Lighting Engineers, Rugby.

ILE (2006). Street Lighting – Invest to Save. Reduction or removal of street lighting (LB1). *Interim Advice Note*. Institution of Lighting engineers, Rugby.

McNeill, G (1999). Street lighting: a developmental and economic history since 1924 (V64, No.2, March/April 1999). *The Lighting Journal*. Institution of Lighting engineers, Rugby.

Raynham, P (2004). An examination of the fundamentals of road lighting for pedestrians and drivers (Vol 36, No 4, pp 307-316). *Lighting Research and Technology*.

UKLB (2004). Well-lit highways. Code of practice for highways lighting management. UK Lighting Board. The Stationery Office (TSO), Norwich. ISBN 0 11552 632 3.

UKRB (2005). Well-maintained Highways. Code of Practice for Highway Maintenance Management. UK Roads Board. The Stationery Office (TSO), Norwich. ISBN 0 11552 643 9.

Appendix A Glossary of terms and abbreviations

Term	Description
Ballast	All discharge lamps have a high electrical resistance when cold and a low resistance after warming up. The electromagnetic ballast is a simple series inductor or "choke", which limits the lamp current. This inductor has significant resistive and inductive losses. For a 150W ballast these losses might amount to 15%.
CFL	Compact fluorescent lamp
CMH	Ceramic metal halide
CRI	Colour rendering index (R_a – general colour rendering index). An index representing the colour shift that coloured surfaces undergo when lit by the given light source compared with the colour of the same surfaces under a reference source of comparable colour-temperature. CRI values range from 0 to 100, where 100 represents the reference source. A high CRI does not necessarily guarantee good colour rendition, unless the reference itself renders colours well. The colour rendering of a light source should be compared with daylight if its correlated colour temperature is >5000K and to a black body source if it is not.
Cut-off	Provides a rapid reduction in luminous intensity in the region between 80° and the horizontal.
Cut-off (semi)	Provides a less severe reduction in the same region.
DLOR	Downward light output ratio. The ratio of the light emitted in the lower hemisphere to the light emitted by the lamp
Efficacy	The ratio of total light output of a lamp in Lumens to the energy input to the lamp in watts.
Electronic control gear	This replaces the electromagnetic ballast. It uses fast electronic switching to control the lamp current by providing it with a high-frequency series of current pulses. It also can also produce the initial high-voltage starting pulse and may have other control functions such as dimming and be programmable. An electronic control gear controlling a 150W lamp would typically have losses of 5%.
Glare	An effect of light which is so much brighter than the current adaptation level that either visual impairment or discomfort is caused. See "disability glare" and "discomfort glare".
Glare (disability)	Glare that impairs the vision of objects, caused by light scattering within the eye.
Glare (discomfort)	Glare which causes discomfort without necessarily impairing the vision of objects. The degree of discomfort depends on the intensity of the light source, its position in the field of view and on the background luminance.
High-pressure discharge	A class of lamps in which an arc is struck between electrodes in a small quartz or polycrystalline alumina (ceramic) arc tube. This contains a metallic dose and a starting gas at relatively high pressure compared with low-pressure lamps. The metallic does vaporises as the lamp warms up.
HPS	High pressure sodium

Ignitors	Ignitors provide a brief, high voltage pulse or pulse train to ionise the gas between the electrodes of a high-pressure discharge lamp.
Illuminance	Density of luminous flux falling on a surface. The measurement unit is the Lux (Lumens/m^2) – symbol Lx.
Illuminance (hemispherical)	Luminous flux on a small hemisphere with a horizontal base, divided by the surface area of the hemisphere
Illuminance (horizontal)	Illuminance on a horizontal plane
Illuminance (semi-cylindrical)	Total luminous flux falling on a curved surface of a very small semi-cylinder divided by the curved surface area of the semi-cylinder.
Illuminance (vertical)	Illuminance on a vertical plane
Initial light output of a lamp	The light output after 100 hours burning from new
Lamp lumen maintenance factor	The proportion of the initial light output which remains after a given time as a result of *lumen depreciation*
Lamp life	The operating time after which a stated proportion of the lamps has failed. Lamp life is approximately normally distributed. Manufacturers often quote life to 50% failure.
LED	Light emitting diode
LOR	Light output ratio. The ratio of the light emitted by the luminaire to the light emitted by the lamp.
LPS	Low pressure sodium
Lumen depreciation	Continuous loss of output throughout life common to all high-pressure discharge lamps. Varies according to the type of lamp.
Luminaire maintenance factor	The ratio of the light output of a luminaire in a specified state of dirtiness to the light output when clean
Luminance	Radiance weighted by a spectral function representing human visual perception of brightness. Unit candelas per square metre – symbol Cd/m^2
MH	Metal halide
PECU	Photo-electric control unit
Radiance	Summation of the power spectrum of radiated energy (in watts)
ULOR	Upward light output ratio. The ratio of the light emitted in the upper hemisphere to the light emitted by the lamp
Utilisation factor	The proportion of the light emitted by the lamp which reaches the area intended to be lit
WLC	Whole life cost

Appendix B Costs of equipment

Table B1 Example lamp costs lamps

Lamp type	Minimum cost	Maximum cost	Typical cost
SON (HPS)	£6 (70W)	£11 (400W)	£8
CMH	£19 (35W)	£25 (400W)	£20
CFL	£4 (36W)	£5 (80W)	£4.50
SOX (LPS)	£13 (35W)	£22 (135W)	£20

Table B2 Example luminaire costs

Road Category	Type	Wattage	Average cost
Motorway (Cat 1)	Flat Glass	400 Watt	£240
Strategic Route (Cat 2)	Curved Glass	250 Watt	£184
Strategic Route (Cat 2)	Flat Glass	250 Watt	£131
Main Distributor (Cat 3a)	Curved Glass	150 Watt	£168
Main Distributor (Cat 3a)	Flat Glass	150 Watt	£121
Secondary Distributor (Cat 3b)	Curved Glass	100 Watt	£127
Link Road (Cat 4a)	Deep Bowl	100 Watt	£120
Local Access Road (Cat 4b)	Dished Polycarbonate	70 Watt	£105
Side Road (Cat 4b)	Bowl	50/70 Watt	£101
Side Road (Cat 4b)	Curved Glass	50/70 Watt	£113
Side Road (Cat 4b)	Flat Glass	50/70 Watt	£107
Side Road (Cat 4b)	Bowl	35 Watt	£115
Side Road (Cat 4b)	Curved Glass	35 Watt	£120
Side Road (Cat 4b)	Flat Glass	35 Watt	£120

Table B3 Example costs of control gear

Equipment type	Wattage	Minimum cost	Maximum cost	Average cost
Electronic ballasts	50/70 Watt	£20	£32	£26
	100 Watt	£24	£55	£39.50
	150 Watt	£26	£55	£40.50
	250 Watt	£53	£53	£53
	400 Watt	£63	£63	£63
Inductive ballasts	All Wattages	£6	£40	£23
PECU*	NA	£6	£15	£10.50
Isolators	NA	£6	£20	£13
Ignitors	NA	£4	£9	£6.50

*Photo-Electric Control Unit

Appendix C Predictions of savings due to dimming

Table C1 Example of energy savings due to "late night" dimming for 50% of lighting hours and dimming to compensate for lumen depreciation (from Crabb *et al*, 2005)

	Lumen compensation dimming steps			"Late-night" dimming steps					
Dimming step	**Total duration (hours)**	**"Normal" input power (W)**	**"Normal" duration (hours)**	**Dimming step**	**"Reduced" input power (W)**	**Dimmed duration (hours)**	Total power used without dimming based on 149W (kWh)	Total power used with dimming (kWh)	Energy saved (kW hours)
3	620	116	310	6	86	310	92.4	62.6	29.8
2	1,186	128	593	6	86	593	176.7	126.9	49.8
1	5,333	137	2667	6	86	2667	794.6	594.5	200.0
0	6,861	149	3431	5	94	3431	1022.3	833.6	188.7
Totals	14,000		7000			7000	2086	1618	468

Energy saved compared with no dimming over an assumed life of 14,000 hours = 22.4%

Notes:

1. Dimming steps given are for the Knobel "Stepdim" 8 step dimmer, which has 10W steps, and the lumen depreciation element is based on the GE CMH lamp, both as used at TRL and in Albi in the Numelite project.
2. The table shows how the application of progressively higher power input with time can compensate for the lumen depreciation of the lamp, thus maintaining a more constant output over the life of the lamp. In the example given, this output is 74% of the full-power output of a new lamp. The "total duration" column gives the duration of each lumen-compensation dimming step, while the "dimmed duration" shows the duration of the "late-night" component of the running hours (in this example assumed to be 50% of the lighting hours). As shown in the "reduced" input power column, the minimum power setting has been constrained by the lowest acceptable input power for the lamp.
3. A greater number of dimming steps would provide finer control, and potentially greater energy savings.

Table C2 Current savings due to dimming provided by Case 1

Costs - Full Power				
Lamp power (W)	Circuit power (W)	Burning hours	Energy price (£/kWh)	Annual cost (£)
150w	179.300	4155	0.05	37.25
250w	319.000	4155	0.05	66.27
400w	457.900	4155	0.05	95.13

Costs – Part night dimmed							
Lamp power (W)	Dimming state	Circuit power (W)	Percentage of full-power (%)	Burning hours	Energy price (£/kWh)	Cost (£)	Annual cost (£)
150w	full	179.300	100.00	2236	0.05	20.05	
150w	dimmed	94.800	52.87	1919	0.05	9.10	29.14
250w	full	319.000	100.00	2236	0.05	35.66	
250w	dimmed	167.900	52.63	1919	0.05	16.11	51.77
400w	full	457.900	100.00	2236	0.05	51.19	
400w	dimmed	235.000	51.32	1919	0.05	22.55	73.74

Savings				
Lamp (W)	Full power (£)	Dimmed (£)	Savings (£)	Saving (%)
150w	37.25	29.14	8.11	21.77%
250w	66.27	51.77	14.50	21.88%
400w	95.13	73.74	21.39	22.48%

Appendix D Lighting questionnaire

CSS LIGHTING GROUP RESEARCH - SURVEY OF STREET LIGHTING SPECIFICATIONS FOR NEW AND REPLACEMENT SCHEMES - 2008

1 Does your authority have policy guidelines which specify the lighting class to be used on different categories of road? *Please select from dropdown list:-*

2 If you answered **YES** to Q1 are lighting classes specified according to BS 5489:2003 and BSEN13201? *Please select from dropdown list:-*

3 If you answered **NO** to Q2 what lighting classes are specified?

4 Are the categories of road and footway you use those in the UK Roads Board's "Well maintained highways" publication? *Please select from dropdown list:-*
(Reference - see Tables 1 and 2)

5 If you answered **NO** to Q4 what other categorisation is used?

*Please indicate the **highest** lighting class specified for each carriageway category in the table below*

Category	Carriageway Hierarchy	Type of Road	ROAD LINKS BSEN 13201 lighting class *OR* other class or units (please specify)	CONFLICT AREAS BSEN 13201 lighting class *OR* other class or units (please specify)
1	Motorway	Limited access, motorway regulations apply		
2	Strategic Route	Trunk and some Route Principal 'A' roads between Primary Destinations		
3a	Main Distributor	Major Urban Network and Inter-Primary Links. Short - medium distance traffic.		
3b	Secondary Distributor	Classified Road (B and C class) and unclassified urban bus routes carrying local traffic with frontage access and frequent junctions		
4a	Link Road	Roads linking between the Main and Secondary Distributor Network with frontage access and frequent junctions		
4b	Local Access Road	Roads serving limited numbers of properties carrying only access traffic		

*Please indicate the **highest** lighting class specified for each footway category in the table below*

Category	Footway Hierarchy	Footway Hierarchy	BSEN 13201 lighting class *OR* other class or units (please specify)
1a	Prestige Walking Zones	Very busy areas of towns and cities with high public space and streetscene contribution.	
1	Primary Walking Routes	Busy urban shopping and business areas and main pedestrian routes.	
2	Secondary Walking Routes	Medium usage routes through local areas feeding into primary routes, local shopping centres etc.	
3	Link Footways	Linking local access footways through urban areas and busy rural footways.	
4	Local Access Footways	Footways associated with low usage, short estate roads to the main routes and cul-de-sacs.	

FACTORS CONSIDERED IN SPECIFYING LIGHTING

6 How are the following factors (Road safety, Security, Intrusive light, Energy consumption) ranked in terms of their importance for the different road categories 1 = lowest ; 4 = highest? *Please select from dropdown lists:*

Category	Carriageway Hierarchy	Type of Road	Safety*	Security* *	Energy consumption	Intrusive or stray light
1	Motorway	Limited access, motorway regulations apply				
2	Strategic Route	Trunk and some Route Principal 'A' roads between Primary Destinations				
3a	Main Distributor	Major Urban Network and Inter-Primary Links. Short - medium distance traffic.				
3b	Secondary Distributor	Classified Road (B and C class) and unclassified urban bus routes carrying local traffic with frontage access and frequent junctions				
4a	Link Road	Roads linking between the Main and Secondary Distributor Network with frontage access and frequent junctions				
4b	Local Access Road	Roads serving limited numbers of properties carrying only access traffic				

***Safety - for traffic routes this relates to the risk of accidents involving vehicles; for pedestrian routes, the feeling of safety and security.**
****Security - the perception of the effect of lighting on crime**

INTRUSIVE OR STRAY LIGHT

7 Does your lighting policy specify compliance with the "Obtrusive light limitations for exterior lighting installations" in the Environmental Zones categorised in the ILE document "*Guidance Notes for the Reduction of Obtrusive Light (GN01)*" as listed in the table below? *Please select from dropdown list:-*

Reference

Category	Description	Examples
E1:	Intrinsically dark landscapes	National Parks, Areas of Outstanding Natural Beauty, etc
E2:	Low district brightness areas	Rural, small village, or relatively dark urban locations
E3:	Medium district brightness areas	Small town centres or urban locations
E4:	High district brightness areas	Town/city centres with high levels of night_time activity

Lighting questionnaire (continued)

8 If you answered **NO** to Q7 please specify below what controls, if any, are placed on intrusive or stray light:

Category	Description	Controls
E1:	Intrinsically dark landscapes	
E2:	Low district brightness areas	
E3:	Medium district brightness areas	
E4:	High district brightness areas	

LIGHTING EQUIPMENT

9 Do you have policies that cover the specification of the following:

Please select from dropdown lists:-

Lamp type

Time/traffic flow dependant dimming

Extinguishing lamps at certain times

Centralised monitoring of the of lighting systems

Centralised remote control of the lighting systems

Passive safety of lighting columns as detailed by DMRB TA 89/05
(Now being superceded by the National Annex to EN 12767:2007)
Reference

If you answered **YES** to any part of Q9 please give details (including such items as lamp wattage, luminaire type, details of control gear e.g. dimmable, electronic)

Please indicate below your specified lamp and luminaire types for each category of carriageway: *Select from drop-down lists*

Category	Carriageway Hierarchy	Carriageway Hierarchy	Lamp type	Luminaire type	If "other" please specify
1	Motorway	Motorway			*For example, if policy is different dependant on location; e.g. urban/rural*
2	Strategic Route	Strategic Route			
3a	Main Distributor	Main Distributor			
3b	Secondary Distributor	Secondary Distributor			
4a	Link Road	Link Road			
4b	Local Access Road	Local Access Road			

Please indicate below your specified lamp and luminaire types for each category of footway: *Select from drop-down lists*

Category	Footway Hierarchy	Footway Hierarchy	Lamp type	Luminaire type	If "other" please specify
1a	Prestige Walking Zones	Very busy areas of towns and cities with high public space and streetscene contribution.			
1	Primary Walking Routes	Busy urban shopping and business areas and main pedestrian routes.			
2	Secondary Walking Routes	Medium usage routes through local areas feeding into primary routes, local shopping centres etc.			
3	Link Footways	Linking local access footways through urban areas and busy rural footways.			
4	Local Access Footways	Footways associated with low usage, short estate roads to the main routes and cul-de-sacs.			

MAINTENANCE

Further comments

10 What is your normal interval between cleaning luminaires? **months**

11 Do you burn lamps to extinction or change them in batches? *Please select from dropdown list:-*

12 What method/s do you use to ensure current lighting standards are met? *Please select from dropdown list:-*

Other

GENERAL

13 Does existing policy for new or replacement schemes make careful selection of the appropriate lighting class using a current guidance document? *Please select from dropdown list:-*

14 If BS 5489-1 Annex B is used, when selecting S classes is use made of the possibility to reduce levels when white light is used?

15 If you answered no to Q13, do you feel it would it be useful to have a guide which advised on the 'maximum' light level required and given by current lighting technologies, which may *Please select from dropdown list:-*

16 Does your current policy for new or replacement schemes specify the use of electronic control gear for discharge lamps? *Please select from dropdown list:-*

17 Are you happy to be consulted further by TRL to discuss particular lighting changes which you have undertaken which might provide useful case histories for use in our guidance document? *Please select from dropdown list:-*

Appendix E Questionnaire responses in full

E.1 Coverage

A total of 22 questionnaires were returned to TRL from

11 English County/City Councils

3 English London Boroughs,

5 Scottish Councils,

2 Welsh Councils and

1 Covering Northern Ireland.

This gave a good spread of geographic areas and size of Council. The Councils which took part are listed below.

English City Councils

Birmingham City

Portsmouth City

English County Councils

Buckinghamshire County

Cheshire County

Cornwall County

Durham County

Essex County

Hertfordshire County

Lancashire County

Suffolk County

West Sussex County

English London Boroughs

Hackney Borough

Islington Borough

Sutton Borough

Scottish City Councils

Dundee City

Glasgow City

Scottish County Councils

South Lanarkshire County,

West Lothian County

Scottish Unitary Council

Fife Unitary

Welsh City/County Councils

Caerphilly County

Cardiff City

Northern Ireland

Northern Ireland region

E.2 The results for each question

These are given below with any comments that the respondents made also included. The most frequent answers are highlighted in yellow as appropriate.

Q1. Does your authority have policy guidelines which specify the lighting class to be used on different categories of road ?

Yes 21 (95%), No 1 (5%)

Q 2. If you answered Yes to Q1 are lighting classes specified according to BS 5489-2003 and BSEN13201 ?

Yes 20 (95%), Mostly but not exclusively 1 (5%)

Q3. If you answered No to Q2 what lighting classes are specified ?

Note 1. The policy only refers to zonal areas and reference is made that all schemes submitted for approval must be designed to current standards and professional guidelines.

Q4. Are the categories of road and footway you use those in the UK Roads Board's "Well maintained highways" publication ?

Yes 17 (81%), No or other 4 (9%), NA 1

Q5. If you answered No to Q4 what categorisation is used ?

Note 1. The only categorisation document referred to is 'The Road Lighting Maintenance Code of Good Practice' published by the LGA.

Note 2. Category 4b not used

Note 3. We are currently updating our database in line with this publication

Table E1 Ranking of highest lighting classes specified for carriageway links

Link	ME1	ME2	ME3a	ME3b	ME4b	S1	S2	S3	NA
Cat 1	**5**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**15**
Cat 2	**1**	**12**	**3**	**0**	**0**	**0**	**1**	**1**	**2**
Cat 3a	**1**	**8**	**6**	**1**	**0**	**0**	**1**	**1**	**1**
Cat 3b	**1**	**4**	**5**	**3**	**1**	**0**	**2**	**2**	**1**
Cat 4a	**1**	**0**	**1**	**1**	**6**	**4**	**2**	**2**	**2**
Cat 4b	**0**	**0**	**0**	**1**	**3**	**3**	**5**	**3**	**1**

Key

Rank	Highest	2nd	3rd	4th

Note. Table 1 includes the following where more than one class specified

Cat 3b. Most onerous from ME3a or S2 both at R_a 20 or above; or, most onerous from ME3b or S3, both at R_a 60 or above

Cat 4a. ME5b

Cat 4a. ME4b or S1 (2 respondents)

Cat 4a. S2 or S3 for $R_a \geq 60$

Cat 4b. ME4b or S1

Cat 4b. S4/S3/S2 depending on crime stats

Cat 4b. S3 or S4 for $R_a \geq 60$

Most commonly work to S2 when not using old BS

Table E2 Ranking of highest lighting classes specified for carriageway conflict areas

Link	CE0	CE1	CE2	CE3	CE4	CE5	S1	NA
Cat 1	**3**	**1**	**0**	**0**	**0**	**0**	**0**	**14**
Cat 2	**1**	**10**	**6**	**0**	**0**	**0**	**0**	**4**
Cat 3a	**0**	**10**	**6**	**2**	**0**	**0**	**0**	**3**
Cat 3b	**0**	**5**	**7**	**2**	**2**	**0**	**0**	**3**
Cat 4a	**0**	**1**	**1**	**9**	**0**	**2**	**1**	**4**
Cat 4b	**0**	**1**	**0**	**3**	**5**	**2**	**3**	**5**

Key

Rank	Highest	2nd	3rd	4th

Note. Table 2 includes the following where more than one class specified

Cat 2 and Cat 3a. CE1 at R_a 20 or above

Cat 2 and Cat 3a. CE1 and CE2

Cat 3b. CE2 at R_a 20 or above; or, CE3 at R_a 60 or above

Cat 4b. S3 at R_a 60 or above

Cat 4b. CE4 and S1

All Cats. To be determined by accident data

Table E3 Ranking of highest lighting classes specified for footways

Link	CE1	CE2	CE3	S1	S2	S3	S4	S5	S6
Cat 1a	**8**	**2**	**1**	**3**	**0**	**2**	**0**	**0**	**0**
Cat 1	**3**	**6**	**1**	**5**	**0**	**0**	**1**	**0**	**0**
Cat 2	**0**	**0**	**3**	**3**	**2**	**5**	**3**	**1**	**0**
Cat 3	**0**	**0**	**0**	**1**	**3**	**7**	**5**	**3**	**0**
Cat 4	**0**	**0**	**0**	**0**	**3**	**4**	**8**	**2**	**1**

Key

Rank	Highest	2nd	3rd	4th

Note. Table includes the following where more than one class specified

Cat 1a and Cat 1. Hybrid – 37 to 43 lux at minimum uniformity 0.4 and minimum Ra 60.

Cat 2, Cat 3 and Cat 4. S3 at R_a 60 or above

Cat 2 and Cat 3. S2 (S3 R_a>60)

Cat 3. S2 or S3 depending on crime stats

Cat 4. S4, S3 or S2 depending on crime stats

As main carriageway and surround ratio

This is covered under the lighting class for the road

Most commonly work to S2 when not using old BS

Q6. How are the following factors (Road safety, Security, Energy consumption and Intrusive or stray light. (1 = Lowest, 4 = Highest)

Table E4 Priority of safety, security, energy and light intrusion

	Safety	Security	Energy	Light intrusion
Cat 1	3.1	1.6	2.8	2.4
Cat 2	3.1	2.1	3.0	2.3
Cat 3a	3.1	2.1	2.9	2.3
Cat 3b	3.3	2.5	2.6	2.3
Cat 4a	3.3	2.5	2.5	2.4
Cat 4b	3.2	2.9	2.4	2.3

Table E4 shows that on average Safety is the most important and on average Energy is the next most important except for category 4b where Security is the second most important.

Q7. Does your lighting policy specify compliance with the "obtrusive light limitations for exterior lighting installations" in the Environmental Zones categorised in the ILE document (GN01)?

Yes 14 (67%), No 7 (33%), NA 1

Q8. If No to Q7, specify below what controls, if any are placed on intrusive or stray light.

Respondent 1 of 7

No answer

Respondent 2 of 7

E1 & E2. Cut off/flat glass

E3 & E4. Semi cut off

Respondent 3 of 7

E1. Very limited lighting to glare class 4-6

E2. Split into two zones, E2a rural small villages, E2b rural large villages , different codes used, care taken with stray light

E3. Light allowed to fall on house frontages to provide vertically illuminated surfaces glare class 1-3 used

E4. Usually decorative equipment, aesthetics of equipment takes precedence over strict light control.

Respondent 4 of 7

E1 to E4. None at the moment - G classifications limits to be introduced

Respondent 5 of 7

E1 to E4. Road Lantern specifications includes ULOR not greater than 2.5%.

Respondent 6 of 7

E1 to E4. Each design is looked at individually. Low Profile Lanterns are used and if necessary Flat Glass. Light shields can be fitted where required.

Respondent 7 of 7

As GN01

Q9. Do you have policies that cover the following?

Table E5 Types of policy in operation

Policy	Yes	No	NA
Lamp type	18 (86%)	3 (14%)	1
Dimming	3 (14%)	18 (86%)	1
Extinquishing	5 (24%)	16 (76%)	1
Central monitoring	4 (19%)	17 (81%)	1
Central remote	4 (19%)	17 (81%)	1
Passive safety	6 (29%)	15 (71%)	1

One respondent who answered 'yes' regarding policy in (Q9) provided this additional information.

Time/traffic flow dependant dimming – The policy is not to dim because presently there is no cost benefit to installing the necessary equipment, except in new housing developments where the developer (house owner) pays.

Extinguishing lamps at certain times – The extinguishing is limited to a small number of high wattage lamps in a small number of areas, where every second lamp is extinguished. For lower wattages there is no cost benefit to installing the necessary equipment and no demonstrable appetite for widespread extinguishing.

Centralised monitoring of the lighting systems – The policy is not to have centralised monitoring as presently there is no cost benefit to installing the necessary equipment.

Centralised remote control of the lighting systems – The policy is not to have centralised remote control as presently there is no cost benefit to installing the equipment.

Passive safety of lighting columns – The policy is not to purchase specialised lighting columns as no cost benefit can be demonstrated for Council roads. The number of injuries arising from accidents involving lighting columns is very low.

Details given by other respondents to Q9

Note 1. Lamp type - Min CRI of 23; extinguishing lamps; PECU 70 lux rating.

Note 2. To increase the use of HPS lighting within existing budgets, balancing the benefits of improved lighting against additional energy costs.

Note 3. Standard lamp types are 35W and 70W CDM 70W 100W AND 150W SON. Lanterns are generally shallow bowl but can vary. Electronic gear on trial but not generally used yet - too expensive. No dimming. Trials also of Cosmopolis and LED sources

Note 4. White light specified for residential and city centre areas, typically 36/55w PLL and 45/65w Cosmo: Part night lighting policy on residential sttreets, 33,000 lights currently

Note 5. Currently 150watt, 100watt, 70watt, 50 watt Sont+ 60 and 70 watt cosmopolis, Phillips Iridium and Urbis ZX range, Harvard Electronic Leafnut Control Gear, Leafnode/Branchnode (currently being installed), fully dimmable. (Staff training taking place)

Note 6. All lamps shall have a colour temperature equal to or better than 1950K and an R_a* colour rendering index of equal to or greater than 25. The IP rating for all luminaires shall be a minimum of IP65.

Note 7. Within the latest Road Lighting Policy (draft) guidance is given with regards where certain lamp types and luminaires should be used. Guidance on the type and switching ratios of photocells are also provided. Despite the absence of specific policies, references are made within the proposed Road Lighting Policy (draft) to dimming, remote monitoring and passive safety.

Note 8. Various HPS 70, 100, 150, 250

Note 9. Lamp type CDO, PLL, HPS. Lantern shallow bowl/curved tempered glass. electronic gear non dimmable. Lamp wattage 150/55/36/70

Note 10. Equipment specifications available on request

Note 11. Lamp type policy is White Light, concentrating on Cosmopolis We are just about to start some trials with remote monitoring systems, waiting for equipment to arrive. The use of such systems will be written into the new lighting policy. Passive safety columns are being used where necessary, but not yet detailed in specification.

Note 12. All road lighting lamps specified to indicate Colour Index, colour temperature, Initial lamp lumens, lumen maintenance at x (hrs), life expectancy at y (hrs), and lamp circuit watts. (x and y varying depending on lamp type source)

Note 13. New lanterns installed are compatible to enable option of remote monitoring . Some locations are currently trialling the technology including the facility to dim in certain locations i.e. Park and Ride car parks.

Note 14. All new installations and conversions lamps shall be High Pressure sodium unless otherwise agreed

Note 15. High Pressure Sodium (SON/T +), Cosmopolis (CPO), Ceramic discharge Metal Halide (CDM).

Table E6 Type of lamp used (carriageway)

Lamp	HPS SON	MH or CMH	CFL	NA	other
Cat 1	6 (86%)	0	0	15	1
Cat 2	17 (85%)	1	0	2	2
Cat 3a	18 (86%)	1	0	1	2
Cat 3b	18 (86%)	1	0	1	2
Cat 4a	15 (75%)	1	2	2	2
Cat 4b	15 (71%)	0	3	1	2

Other response: Cat 3b (HPS SON) or any lamp having R_a 60 or above, Cat 4b Any lamp having R_a 60 or above

Table E7 Type of luminaire used (Carriageway)

Luminaire type	Shallow	Deep	Flat	NA	Other
Cat 1	1	0	4 (67%)	16	1
Cat 2	14 (70%)	1	5	2	0
Cat 3a	15 (71%)	1	5	1	0
Cat 3b	17 (81%)	2	2	1	0
Cat 4a	17 (85%)	3	0	2	0
Cat 4b	17 (81%)	4	0	1	0

Other responses:

Cat 3a, 3b, 4a, 4b Sox lighting on old schemes

Cat 2, 3a, 3b, 4a, 4b Can vary owing to the nature of the County Councils Environment

Cat 2, 4a, 4b (shallow bowl or flat glass), Cat 3a 3b (shallow bowl or flat glass, or decorative)

Cat 2, 3a, 3b, 4a, 4b Flat glass some locations

Cat 2, 3a, 3b, 4a, 4b Cosmo also used

Cat 3a, 3b, 4a, 4b can also be flat glass

Cat 2, 3a, 3b, 4a, 4b Cosmopolis CPO-TW

Cat 2, 3a, 3b, 4a, 4b The choice of bowl type depends on design and road location

Table E8 Type of lamp used (Footway)

Lamp	HPS SON	MH or CMH	White SON	CFL	Other	NA
Cat 1a	4	9	2	0	5	1
Cat 1	8	5	2	0	5	1
Cat 2	9	2	1	3	5	1
Cat 3	8	1	1	5	4	1
Cat 4	8	1	1	5	4	2

Table E9 Type of luminaire used (Footway)

Luminaire type	Shallow	Deep	Flat	Other	NA
Cat 1a	12	3	1	5	1
Cat 1	12	3	1	5	1
Cat 2	14	4	0	3	1
Cat 3	10	8	0	3	1
Cat 4	12	5	0	3	2

Other responses:

Cat 1a, 1, 2, 3, 4 Any lamp having R_a 60 or greater

Cat 1a, 1 Contingency theory - it all depends on the circumstances

Cat 2, 3, 4 Linear footpath - post mount, Non-linear footpath - post top

Cat 1a, 1, 2, 3, 4 Light source and luminaire types vary depending on brief

Cat 1a 1 Generally the lanterns are specialist treatment

Cat 1a, 1, 2 or flat glass, or decorative. Some ceramic metal halide lamps Cat 3 & 4 or decorative. Some ceramic metal halide lamps.

Cat 1a, 1, 2, 3, 4. CosmoPolis

Cat 1a &1 Moving to CDM white light

Cat 3 SON(HPS) and CFL subject to (road) width

Cat 1a & 1 Decorative

Cat 1a & 1 Can also be heritage/modern deco, of various shapes and sizes.

Cat 1a, 1, 2, 3, 4. Cosmopolis CPO-TW

Cat 1a, 1, 2, 3, 4 The choice of bowl type depends on design and road location

Q 10. What is the normal interval between cleaning luminaires ?

Table E10 Number of councils with given time interval between cleaning

Months	12	18 & 24	24	36	48	72	Other	NA
Number.	2	1	2	8	2	1	5	1

Other responses:

SOX 24 months; CDM/T 24 months; HPS 36 months; SON/PIA 48 months

We only clean at lamp change. With modern luminaires and cleaner air than say 40 years ago, only in a few locations is supplementary cleaning required.

Lights to only be cleaned at time of other operations

Cleaning now carried out with BLC at various change frequencies determined by manufacturers recommendations

No cycle, at lamp change

Q 11. Do you burn lamps to extinction or change in batches ?

Batch 14 (67%), Extinction 7 (33%), NA 1

Q 12. What methods do you use to ensure current lighting standards are met ?

- Set frequency of lamp changes 14 (67%) (*see note *)*
- Routine measurement of light output 3 (14%) (*see note *)*
- Other 5 (24%)
- NA 1

Other responses

1. Other methods have disproportionate costs compared to the benefits. In the main, they are advocated only by some involved in PFI projects.
2. Starting light output measurements next year.
3. Night Scouting Only
4. Meeting the BVPI's 3 day repair.
5. With the removal of 'bulk lamp change', no method currently exists to ensure lighting standards are met.
6. None
7. Standard only met for new installations

*** *Note*.** One respondent carried out routine measurement of light output AND set frequency of lamp changes.

Q 13. Does existing policy for new or replacement schemes make careful selection of the appropriate lighting class using a current guidance document?

Table E11 Number of councils using exiting policy

BS5489-1, Annex B	CEN TR 13201-1	Other	NA	No
14	3	1	1	3

Notes:

1. Own Council guidance notes on lighting standards
2. Policy States that all new schemes will be in accordance with BS5489
3. Own Council lighting strategy is based on 13201 but has different selection criterion

Q14. If BS 5489-1 annex B is used when selecting S classes is use made of the possibility to reduce levels when white light is used ?

Yes 14 (70%), No 6 (30%)

Notes:

1. White light reduced levels incorporated into specified tables
2. Only when site conditions prevent required standards from being met
3. Trials are underway using S Class in appropriate situations

Q 15. If you answered No to Q 13 do you feel it would be good to have a guide which advised on the "maximum" light level required and given by current

lighting technologies which may reduce over specifying and ultimately save energy and cost ?

Yes 3, No 0, NA 19

Note 1. Over-lighting can be problem in rural shires where good quality and uniformity is much more important than high levels

Q 16. Does your current policy for new or replacement schemes specify the use of electronic control gear for discharge lamps ?

Yes 13 (65%), No 7 (35%), NA 1, Other 1

Note 1. Only in new housing developments

Q 17. are you happy to be consulted further by TRL ?

Yes 18 (90%), No 2 (10%), NA 2

Note 1. Extensive trials of white light in residential areas, 140w Cosmo trial on strategic route - others to follow.

General comments contained in addition to questionnaire responses

1. Most of our design is in built up urban areas where geographical layout supersedes design spacings. However we do work to S2 most commonly where we are not using the old BS. We have not dealt with any conflict areas since this was introduced. No PFI in Scotland and latest standards are driven by PFI criteria. Overhead lines.
2. I spent ages deliberating over that question! (Question 6)I tried to rank them in order of importance but they are all equally important in an inner city urban area. Prioritisation has to be decided on a road by road basis taking account of accident/crime statistics and police/resident input and cannot be categorised according to road status.
3. Even though our policy document is rather dated and compact, we do specify quite rigid requirements with reference to equipment types as part of our Section 38/278 process, however, from a design point of view, we only stipulate that designs must be in accordance with the current BSEN requirements for the category of highway being lit.
4. Too busy to finish questionnaire.
5. I had a few problems in completing the questionnaire for the following reasons:
    - Footways are generally lit using the same lighting units that are installed to light the main carriageway (in the interest of reducing energy and capital costs), with only separate footways lit to a specific class
    - Lighting for conservation areas, town centres and high crime areas etc is often non-standard

Review of the class and quality of street lighting

TRL was commissioned by TfL to carry out research into the class and quality of street lighting on all types of road on behalf of the sponsoring group. The methodology included a review of standards and guidance documents, a review of costs of a range of lighting equipment and a survey of local authorities' policies and specifications. The report presents the results of the desk study and an analysis of the questionnaire returns. The cost information was used in a whole-life-cost calculation of the hardware and energy costs over a 30-year life, to compare four types of lighting system. These were conventional HPS lamps with electromagnetic gear, HPS with non-dimming electronic gear, Philips Cosmopolis White lamps with similar electronic gear and an HPS system with electronic gear, part-night dimming and central control and monitoring.

The results showed that most of the authorities specify selection of lighting classes within the range of the current British Standard, but that this standard is relatively inflexible compared to the parallel European document. This may in some cases result in the selection of unnecessarily high lighting classes. Most authorities have policies on lamp type, but few have policies on dimming, full or part-night extinguishing, central monitoring and control or passive safety.

The WLC exercise demonstrated that although the more "advanced" systems use the least energy, higher initial costs result in WLCs over 30 years being similar. There should therefore be no serious financial impediment to the installation of the more advanced systems. The report concludes with a set of recommendations which should help local authorities specify optimum lighting for all lighting situations.

Other titles in this series

SL2 Invest to save – sustainable street lighting. P Fox. Mouchel. 2009

SL3 Review of luminaire maintenance factors. A Sanders and A Scott. Mott MacDonald. 2009

SL4 The use of passively safe signposts and lighting columns. G L Williams, J V Kennedy, J A Carroll and R Beesley. TRL Published Project Report PPR342. 2009

SL5a Review of the lighting requirement for traffic signs and bollards. J Cooper, K Stafford, P Owlett and J Mitchell. TRL Published Project Report PPR382. 2009

SL5b Guidance on the lighting requirement for traffic signs and bollards. J Cooper and J Mitchell. TRL Published Project Report PPR383. 2009

Price code: 3X

ISSN 0968-4093

TRL
Crowthorne House, Nine Mile Ride
Wokingham, Berkshire RG40 3GA
United Kingdom

T: +44 (0) 1344 773131
F: +44 (0) 1344 770356
E: enquiries@trl.co.uk
W: www.trl.co.uk

Published by

IHS
Willoughby Road, Bracknell
Berkshire RG12 8FB
United Kingdom

T: +44 (0) 1344 328038
F: +44 (0) 1344 328005
E: trl@ihs.com
W: http://emeastore.ihs.com

ISBN 978-1-84608-769-1

9 781846 087691

SL1/PPR380