E-street Initiative

Work Package 4.4

Comprehensive report

8.8.2008

On behalf of the E-Street project (www.e-streetlight.com)

Intelligent Energy Europe

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1. EXECUTIVE SUMMARY

1.1 Legislation

On rural roads lighting is a cost-effective accident countermeasure. On urban areas lighting provides in addition to the above mentioned general safety, driving comfort and city beautification.

There are no special legislation for outdoor lighting. Relevant European Directives will be justification for development of laws.

1.2 Recommendations and standards

The best known organisation preparing recommendations is The International Commission on Illumination (CIE). The most important document from road lighting point of view is CIE Publication 115 “Lighting of roads for Motor and Pedestrian Traffic”. This will be revised in such a way that lighting performance requirements may vary depending on actual status of environmental and traffic conditions.

CEN/TC 169 has agreed to re-establish the CEN/TC 169/226 JWG (Joint Working Group) with the task to revise and develop all parts of EN 13201.

1.3 National guidelines

Extent and accuracy of the existing guidelines vary moderately. Some countries have their own national road lighting policy. European standards especially EN 13201, are widely adopted. Adaptive road lighting is already mentioned in few cased.

Findings of the E-street project will provide relevant basis for further development of national guidelines.

1.4 Relationship with VITO study

In the VITO study *“Preparatory Studies for Eco-design Requirements of EuPs, Final Report Lot 9: Public street lighting, January 2007”* reference is being made to the E-Street project on intelligent street lighting under the heading ‘energy saving potential by light dimming’. There are four relations mentioned that justify dimming according to local conditions, i.e. dimming related to traffic volume, dimming related to weather conditions, fine tuning to adapt to local parameters (e.g. geometry, road surface), and dimming to compensate for lamp lumen depreciation. Energy savings are estimated to be between 16 % (magnetic ballast) and 22 % (electronic ballast) based on 6 hours bi-level dimming out of typical 11 hours daily operation. This possible energy saving is converted into a so-called ‘ballast gain factor’ which is used in the calculation of the annual energy consumption. The recommendations to complement the European existing documents of CEN are summarized in the VITO study as follows:

“The European standard EN 13201-2 gives only minimum requirements but no maximum light levels.”

This is true in general, but in the majority of cases the installed lighting levels will not exceed the levels prescribed following the selection procedure of CEN/TR 13201-1. For lighting classes S there is a limit (1.5 times the average illuminance required for the class) specified in the European standard EN 13201-2 for the actual average illuminance to achieve the minimum illuminance required.

"The CEN Technical Report TR 13201-1 offers no clear solution for dimming applications as it determines traffic volume on a daily bases."

Here the revised CIE publication *"Lighting of Roads for Motor and Pedestrian Traffic, final draft of revised CIE Publication 115:200X, 2008"* offers much more flexibility not only considering traffic volume but also a number of other time dependent parameters like speed, traffic composition and/or ambient luminance.

Although in the calculation of energy consumptions temporarily reduced lighting levels (of adaptive lighting system) are taken into account (indirectly using e.g. the 'ballast gain factor'), the finally suggested bench mark values to measure energy efficiency are based on lighting power densities (LPD) only in accordance with the VITO study. For best available technologies (BAT) the values are 0.25 $W/m^2/cd/m^2$ for ME lighting classes and 0.03 $W/m^2/lx$ for CE and S lighting classes, the maximum values are 0.5 $W/m^2/cd/m^2$ for ME lighting classes and 0.06 $W/m^2/lx$ for CE and S lighting classes respectively. These values would apply to the 100 % level of adaptive lighting systems. Used as the only energy efficiency measure lighting power densities (LPD) do not offer any incentives to install intelligent controls and adaptive lighting systems. There is still a need to specify an additional energy efficiency measure based on the annual energy consumption, whether total or related to the area considered, to the lighting level, or to both. This should be the task of an appropriate CEN working group which is going to extent and/or to revise the considered European documents on road lighting including the European standard EN 13201- all parts.

2. STARTING POINTS

2.1 Legislation

The highest rules for road keeping are given in legislation decreed by the Parliament, These are e.g.

- Road Act
- Land use and construction law

Above mentioned laws do not include any technical details. E-street Project can not affect legislation.

A remarkable justification for the E-street project is the Directive 2006/32/EC of 5.4.2006 on energy end-use efficiency and energy services. In accordance with its general forgets member states shall adept and aim to achieve an overall national indicative energy savings target of 9 % for years 2008-2016 to be reacted by way of energy services and other energy efficiency improvement measures. Member states shall take cost-effective, practicable and reasonable measures designed to contribute towards achieving this target. These measures include among others outdoor lighting.

For instance in Finland Ministry of Commerce and Industry has already made agreements with several cities for the saving energy. By the end of 2008 there will be a law, statue or other specification concerning the authorities of government.

2.2 Existing recommendations

2.2.1 International Commission on Illumination (CIE)

2.2.1.1 General

All road lighting matters are included in field of activities of Division 4. Its terms of reference are as follows.

To study lighting and visual signaling and information requirements of transport and traffic, such as road and vehicle lighting, delineation, signing and signaling for all types of public roads and streets, and all kinds of users and vehicles, and visual aids for modes other than road transport.

From the adaptive road lighting point of view the most important technical committee is TC 4-44 “Management and Maintenance of Road Lighting. (Title of TC is developed due to historical reasons and does not in such describe real activities). Terms of reference are: To revise the report CIE 115-1995 “Recommendations for the lighting of roads for motor and pedestrian traffic” in such a way that lighting performance requirements may vary depending on actual status of environmental and traffic conditions.

2.2.1.2 State of the art

The present publication CIE 115-1995 specifies fixed values for lighting parameters and a simple definition for choice of lighting class on different situations. These restrict the modern use of adaptive road lighting in accordance with EuP program and Directive 2006/32/EC on energy end- use efficiency and energy services. Existing extracts are as follows. Quotations are written in italics.

5. QUALITY CRITERIA AND LIGHTING CLASSES FOR MOTOR TRAFFIC

5.2 Choice of lighting class

The lighting recommendations are in classes, M1 to M5, which are selected according to the function of the road, traffic density, traffic complexity, traffic separation, and the existence of facilities for traffic control, such as traffic lights. Typical examples are given in Table 5.1. The descriptions of the road are broad so that they can be interpreted to suit individual requirements for national recommendations. When a selection is made all road users, including motorists, motor and pedal cyclists, and pedestrians should be considered.

Table 5.1 Lighting Classes for different road types

DESCRIPTION OF ROAD	LIGHTING CLASS
High speed roads with separate carriageways, free of crossings at grade and with complete access control; motorways, express roads.	
Traffic density and complexity of road layout *(Note 1)*:	
High	M1
Medium	M2
Low	M3
High speed roads, dual carriageway roads.	
Traffic control *(Note 2)* and separation *(Note 3)* of different types of road user *(Note 4)*:	
Poor	M1
Good	M2
Important urban traffic routes, radial roads, district distributor roads.	
Traffic control and separation of different types of road user:	
Poor	M2
Good	M3
Connecting less important roads, local distributor roads, residential major access roads. Roads which provide direct access to property and lead to connecting roads.	
Traffic control and separation of different types of road user:	
Poor	M4
Good	M5

Note 1 *Complexity of road layout refers to infrastructure, traffic movement, and visual surrounds.*
Factors which should be considered are:
- number of lanes, inclines
- signs, and signals.

Entrance and exit ramps, merging traffic, gores, etc., the presence of which should also be considered, are dealt with in chapter 8, the lighting of conflict areas.

Note 2 *Traffic control refers to the presence of signals and signs, and the existence of regulations.*
Method of control are:
- traffic lights, priority rules, priority regulations and signs, traffic signs, directional signs, and road markings.
Where these are absent or sparse the traffic control is regarded as poor, and vice versa.
Note 3 *Separation may be by means of dedicated lanes or by the restriction of use to one or more of the traffic types. The lower grade of lighting can be considered as appropriate when this separation exists.*
Note 4 *Different types of road user are, for example, motors cars, trucks, slow vehicles, buses, pedal cyclists, and pedestrians.*

5.3 Temporal variation of lighting class according to traffic density

Where the Lighting Class of a road is varied to accord with changes in traffic density during the night to conserve energy (for example, the Lighting Class is lowered after rush hours, the changes should be such that they meet all the requirements of the appropriate higher of lower Lighting Class (that is, if the average luminance of the road surface is reduced to that of lower class, the uniformity and glare criteria of that class shall be fulfilled).

6. REQUIREMENTS FOR MOTOR TRAFFIC – LUMINANCE CONCEPT

The controlling criteria are;
- luminance level und uniformity of the carriageway
-lighting of the surrounds of the road,
- limitation of glare, both disability and discomfort,
- direct visual guidance

The numerical description of the first three criteria and the recommended values for them under various traffic situations are given in Table 6.1. It is not possible at present to quantify direct visual guidance, but reference should be made to clause 6.8 for practical implementation. For advice on appearance and environmental aspects see chapter 10.

The lighting criteria used in Table 6.1 are maintained average road surface luminance (L_{ave}), overall (U_o). and longitudinal (U_l) uniformity of luminance, surround ratio (SR), and threshold increment (TI). A detailed description of these terms is given below. These apply to dry roads; clause 6.7 gives recommendation for wet roads.

Table 6.1. Lighting requirements for motor traffic, based on road surface luminance (NR is no requirement)

LIGHTING CLASS	EXTENT OF APPLICATION				
	All Roads	All Roads	All Roads	Roads with few or no Intersections	Roads with Footways not lit to Classes P1 to P4 in Clause 9.4
	$\bar{L}$ (cd.m^{-2}) Minimum Maintained *Clause 6.1*	U_o Minimum *Clause 6.2*	*TI* (%) Maximum Initial *Clause 6.3*	U_l Minimum *Clause 6.4*	*SR* Minimum *Clause 6.5*
M1	2,0	0,4	10	0,7	0,5
M2	1,5	0,4	10	0,7	0,5
M3	1,0	0,4	10	0,5	0,5
M4	0,75	0,4	15	NR	NR
M5	0,5	0,4	15	NR	NR

8. LIGHTING OF CONFLICTS AREAS

Table 8.1. Lighting requirements for conflict areas

LIGHTING CLASS	$\bar{E}$ (lx) over whole of used surface Minimum Maintained	U_o(E) Uniformity of Illuminance Minimum
C0	50	0,40
C1	30	0,40
C2	20	0,40
C3	15	0,40
C4	10	0,40
C5	7,5	0,40

Table 8.2 gives examples of the application of Table 8.1 to typical conflict areas. In this table the letter in brackets is the Class Number, so, for example, C(N) = M (N-1) would signify that the conflict area class is C2 if the most important road leading in to conflict area is M3.

Examples of the application of Lighting Classes in conflict areas where luminance is not applicable.

CONFLICT AREA	ILLUMINANCE LIGHTING CLASS
Underpasses	C(*N*) = M(*N*)
Junctions, gores, ramps, weaving sections, areas with restricted lane width	C(*N*) = M(*N*-1)
Railroad crossings: simple complex	 C(*N*) = M(*N*) C(*N*) = M(*N*-1)
Roundabouts with no signals: complex or large medium complexity simple or small	 C1 C2 C3
Queuing areas: complex or large medium complexity small or simple	 C1 C3 C5

9. ROAD LIGHTING FOR THE PEDESTRIAN

Table 9.1 Lighting Classes for different road as types in pedestrian areas.

DESCRIPTION OF ROAD	LIGHTING CLASS
High prestige roads	P1
Heavy night-time use by pedestrians or pedal cyclists	P2
Moderate night-time use by pedal cyclists or pedestrians	P3
Minor night-time use by pedal cyclists or pedestrians solely associated with adjacent properties	P4
Minor night-time use by pedal cyclists or pedestrians solely associated with adjacent properties. Important to preserve village or architectural character of environment	P5
Very minor night-time use by pedal cyclists or pedestrians solely associated with adjacent properties. Important to preserve village or architectural character of environment	P6
Roads where only visual guidance provided by the direct light from the luminaires is required	P7

Table 9.2 Lighting requirements for pedestrian traffic.

LIGHTING CLASS	HORIZONTAL ILLUMINANCE (lx) on whole of used surface Maintained	
	AVERAGE *Sub-clause 9.3.1*	MINIMUM *Sub-clause 9.3.1*
P1	20	7,5
P2	10	3
P3	7,5	1,5
P4	5	1
P5	3	0,6
P6	1,5	0,2
P7	Not applicable	Not applicable

2.2.2 European Committee for Standardization (CEN)

2.2.2.1 State of the art

The document CEN/TR13201-1:2004 " Road Lighting Part 1: Selection of lighting classes" has been prepared by Technical Committee CEN/TC 169 "Light and Lighting". This informative technical report recommends the lighting classes set out in the standard EN13201-2 and gives guidelines on the application of these classes.

To do above mentioned, the report includes a system to define an outdoor public traffic area in terms of parameters relevant to lighting. To assist in the applications of classes, it suggests a practical relationship between the various series of lighting classes, in terms of comparable or alternative classes. The parameters used allow:
a) a lighting situation to be described in terms of
- the geometry of the area under consideration
- the use of the area
- the influence of the surrounding environment
b) a specific approach to situations to be taken to enable the effective use of energy.

The process is extremely detailed and complicated. Therefore planners and designers are reluctant to use this recommendation in their practical activities. Following extract from the document gives one representative example. Quotations are written in italics.

4. Outline of selection procedure

This document is arranged in such a way that a step selection procedure may be followed to arrive at the appropriate lighting recommendations:

a) define the public traffic area in one or more relevant areas and select the set of lighting situations (5.1):
b) go to table indicated for the selected set (see Annex A);
c) define the relevant area in detail (see 5.2 and 5.3);
d) select the range of lighting classes;
e) select one lighting class from the range;
f) find the lighting performance requirements for the selected lighting class(es);
g) consider the general recommendations (see Clause 6).

Table 1 — Grouping of lighting situations

Typical speed of main user km/h	User types in the same relevant area			Sets of lighting situations
	Main user	Other allowed user	Excluded user	
> 60	Motorised traffic		Slow moving vehicles Cyclists Pedestrians	A1
		Slow moving vehicles	Cyclists Pedestrians	A2
		Slow moving vehicles Cyclists Pedestrians		A3
> 30 and ≤ 60	Motorised traffic Slow moving vehicles	Cyclists Pedestrians		B1
	Motorised traffic Slow moving vehicles Cyclists	Pedestrians		B2
	Cyclists	Pedestrians	Motorised traffic Slow moving vehicles	C1
> 5 and ≤ 30	Motorised traffic Pedestrian		Slow moving vehicles Cyclists	D1
		Slow moving vehicles Cyclists		D2
	Motorised traffic Cyclists	Slow moving vehicles Pedestrians		D3
	Motorised traffic Slow moving vehicles			D4
	Cyclists Pedestrians			
Walking speed	Pedestrians		Motorised traffic Slow moving vehicles Cyclists	E1
		Motorised traffic Slow moving vehicles Cyclists		E2

A.1 Lighting situations — set A1

Table A.1 — Recommended range of lighting classes

Main weather type	Separation of carriageways	Type of junctions		Traffic flow vehicles per day								
		Interchanges	Intersections	< 15 000			15 000 to 25 000			> 25 000		
		spacing, distance between bridges km	density intersections/km	←	o	→	←	o	→	←	o	→
Dry	Yes	> 3		ME5	ME4a	ME3a	ME4a	ME3a	ME2	ME4a	ME3a	ME2
		≤ 3		ME4a	ME3a	ME2	ME4a	ME3a	ME2	ME3a	ME2	ME1
			< 3	ME5	ME4a	ME3a	ME5	ME4a	ME3a	ME4a	ME3a	ME2
			≥ 3	ME4a	ME4a	ME3a	ME4a	ME3a	ME2	ME3a	ME2	ME 1
	No	> 3		ME4a	ME3a	ME2	ME3a	ME2	ME1	ME3a	ME2	ME1
		≤ 3		ME3a	ME2	ME1	ME3a	ME2	ME1	ME2	ME2	ME1
			< 3	ME4a	ME4a	ME3a	ME4a	ME3a	ME2	ME3a	ME2	ME1
			≥ 3	ME4a	ME3a	ME2	ME3a	ME2	ME1	ME2	ME2	ME1
Wet				Choice as above, but select MEW classes								

Table A.2 — Recommended selection from range

Conflict area	Complexity of visual field	Difficulty of navigational task	Ambient luminance		
			low	medium	high
No	Normal	Normal	←	←	o
		Higher than normal	o	o	→
	High	Normal	←	o	o
		Higher than normal	o	→	→
Yes			→ [a]		

[a] For conflict areas, luminance is the recommended design criterion. However, where viewing distances are short and other factors prevent the use of luminance criteria, illuminance may be used. Comparable CE classes to recommended ME classes can be found in Table 3.

Table 2 — Specific parameters

Parameters		Options
Area (geometry)	Separation of carriageways	Yes No
	Types of junctions	Interchanges Intersections
	Interchange spacing, distance between bridges	>3 km ≤ 3 km
	Intersection density	< 3 intersections/km ≥ 3 intersections/km
	Conflict area	No Yes
	Geometric measures for traffic calming	No Yes
Traffic use	Traffic flow of vehicles per day	< 4 000 4 000 to 7 000 7000 to 15 000 15 000 to 25 000 25 000 to 40 000 > 40 000
	Traffic flow of cyclists	Normal High
	Traffic flow of pedestrian	Normal High
	Difficulty of navigational task	Normal Higher than normal
	Parked vehicles	Not present Present
	Facial recognition	Unnecessary Necessary
	Crime risk	Normal Higher than normal
Environmental and external influences	Complexity of visual field	Normal High
	Ambient luminance	Rural Urban City centre
	Main weather type	Dry Wet

6.2 Lighting classes per sets of situations

The Lighting recommendations are specific to each relevant area. For each set of situations as specified in Table 1, specific recommendations are given in the Tables of Annex A, which each consist of a pair of Tables from Tables A1 to A20.

- *In the "odd numbered" Tables, by consideration of the relevant parameters, a box is selected containing three lighting classes which comprise the recommended range for the particular situation;*
- *In the "even numbered" Tables, a selection from that range is made:*
- *An arrow to the left indicates the lighting class at the left side of the select box;*
- *An Arrow to the right indicates the lighting class at the right side of the selected box*
- *A zero indicates the lighting class in the middle of the selected box*

6.3 Adjacent areas

There should not be a difference greater than two comparable classes between adjacent areas. The area with the highest recommended lighting level is the reference area.

In order for this recommendation to be applied when adjacent areas have lighting recommendations based on luminance and horizontal luminance, Table 3 gives lighting classes of comparable lighting

level, using the " ME/MEW#, " CE " and "S" lighting classes from of EN 13201-2:2003, Tables 1, 2 and 3 respectively.

Table 3 — Lighting classes of comparable1) lighting level

	ME 1	ME 2	ME 3	ME 4	ME 5	ME 6		
	MEW 1	MEW 2	MEW 3	MEW 4	MEW 5			
CE 0	CE 1	CE 2	CE 3	CE 4	CE 5			
			S 1	S 2	S 3	S 4	S 5	S 6

[1] For ME / MEW classes: CIE road surface reflectance of CIE publication 66:1984, Table C.2.

When a carriageway is defined as a separate area, adjacent traffic areas should always be defined and this recommendation applied to ensure adequate lighting of these areas in relation to the carriageway.

When there are no traffic areas adjacent to the carriageway and "ME" lighting classes are used. The surround ratio is applied.

6.4 Alternative an additional lighting classes

The Tables in Annex A give recommendations based on ill-luminance or horizontal luminance.

In some countries there may be a preference for:

- Using hemispherical illuminance alternatively to horizontal illuminance. In this case "Á" lighting classes of EN 13201-2:2003, Table 4 may be applied as alternatives to the recommended "S" lighting classes of EN 13201-2:2003, Table 3, acording to Table 4.

Table 4 – "A" classes of alternative lighting level to "S" classes

Table 4 — « A » classes of alternative lighting level to « S » classes

Reference class	S1	S2	S3	S4	S5	S6
Alternative class		A1	A2	A3	A4	A5

- Adding recommendations to horizontal illuminance by using semicylindrical or vertical illuminance. In this case "ES" or "EV" lighting classes of EN 13201.2:2003, Table 5 or Table 6 can be added to the recommended "CE" or "S" lighting, classes according to Table 5.

Table 5 — « ES » and « EV » classes additional to « CE » or « S » classes

Reference class	CE0	CE1	CE2	CE3 S1	CE4 S2	CE5 S4 S3	S4	S5	SE6
Alternative additional classes	ES1	ES2 EV3	ES3 EV4	ES4 EV5	ES5	ES6	ES7	ES8	ES9

2.3 Existing standards

2.3.1 International Organization for Standardization (ISO)

2.3.1.1 State of the art

The existing joint ISO/CIE standards in the field of road lighting are as follows:

ISO 0526/CIE S005 CIE standard illuminants for colorimetry, 1999.
ISO/CIE 10527 Colorimetric observers, 1991 S002,1986)
CIE S004-2001 Colours of light signals, 2001
ISO 16508/CIE S006 Road traffic light – 200 mm roundel signals photometric properties, 1999

ISO 17166/CIE S007 Erythema reference action spectrum and standard erythema dose,1998.
ISO 8995/CIE S2008-2001 Lighting of indoor work places, 2001
CIE S2009:2002 Photobiological safety of lamps and lamp system, 2002.
ISO 15469/CIE S011:2003 Spatial distribution of daylight - CIE standard general sky.2003.
CIE A013:2003 International standard global UV index, 2003
CIE S010:2004 Photometry – The CIE system of physical photometry, 2004
DS012.3:2004 Standard method of assessing the spectral quality of daylight simulators for visual appraisal and measurement of colour, 2002.
DS015.2:2004 Lighting of work places – outdoor work places, 2002

2.3.2 European Committee for Standardization (CEN)

2.3.2.1 State of the art

There are four existing documents, one informative technical report and three standards. These are worked out by the Joint Working Group of CEN/TC169 “Light and Lighting” and CEN/TC226” Road Equipment”. Mandatory standards are as follows.

EN 13201-2: 2003-Part: Performance requirements

This part of this European Standard defines, according to photometric requirements, lighting classes for road lighting aiming at the visual needs of road users, and it considers environmental aspects of road lighting.

Lighting parameters are defined with fixed values.

One of the basic sources is CIE Publication 115:1995 “Recommendations for the Lighting of roads for roads and pedestrian traffic”.

EN 13201-3:2003-Part 3: Calculation of performance

The calculation methods described in this part enable road lighting quality characteristics to be calculated by agreed procedures so that results obtained from different sources will have uniform basis.

EN 13201-4: 2003-Part4: Methods of measuring lighting performance

This part of standard specifies the procedures for making photometric and related measurements of road lighting installations. Examples are given of the form of test report.

2.4 The VITO study

2.4.1 Introduction

In this chapter document “Preparatory Studies for Eco-design Requirements of EuPs, Final Report Lot 9: Public street lighting, January 2007” is being analyzed with the purpose to find justifications for the adaptive road lighting. Considerations are as follows.

The ratio of the achievable illumination level, expressed in terms of an average luminance or illuminance on a reference surface (here the road surface given by the width of the road and the luminaire spacing) to the necessary (total) electric power, depends on the selected lamps, ballasts (control gear), and luminaires as well as on the luminaire layout. For lamps and ballasts there are appropriate measures, efficacy and ballast-lamp

circuit power respectively, which serve as a basis for the evaluation of energy efficiency. However, for luminaires the obvious measure, the light output ratio, is not a suitable quantity, as there exists no relationship to the achievable illumination level. However, the energy efficiency of particular luminaires in a given layout can be evaluated using the utilisation factor for the specific reference surface. The utilisation factor is defined as the ratio of the luminous flux received by the reference surface to the total lamp flux of the installation. The luminous flux received by the reference surface divided by the size of the reference surface yields the average illuminance, and after multiplication with the average luminance coefficient the average luminance.

This methodology has been used in the VITO study to introduce the “Lighting Power Density” (LDP) as a measure for road lighting energy efficiency. The lighting power density is defined as the ratio of the total power P installed to the total luminous flux Φ received by the reference surface; the total luminous flux Φ in turn is given as product of the average illuminance E and the size A of the area considered, or as the average luminance L divided by the average luminance coefficient q_o times the size A of the area. The luminous flux Φ received by the reference surface is named “Functional Unit” (FU), and is simply the product of the utilization factor UF times the total maintenance factor MF times the total nominal luminous flux of lamps.

From the knowledge of all individual quantities it is possible to calculate (adjusted) total or different specific energy consumptions for a given period of time.

2.4.2 Lighting classes and road categories

For a given situation the appropriate lighting class, and hence the lighting requirements, has to be selected according to the function of the road, the design speed, the overall layout, the traffic volume and composition, and the environmental conditions. In the European standard EN 13201-2 there are in principal three different sets of lighting classes for roads for motorized traffic (ME, MEW), for conflict areas (CE), and for pedestrian areas (S). The lighting class selection procedure is described in the CEN Technical Report TR 13201-1 which has been converted into national standards in a number of member countries. The selection of a ME/MEW lighting class for motorized traffic at high and moderate speed - and also of a CE lighting class for conflict areas - is governed by the parameter traffic flow of vehicles per day; a fixed number not allowing for adaptive lighting levels dependent on actual traffic volumes. The parameters difficulty of navigational task, complexity of visual field, and ambient luminance could be used to justify different time dependent lighting levels, but as the system is not consistent in itself, it is not practical. The selection of a S lighting class for a pedestrian area at low or very low speed offers in principle more possibilities for time dependent lighting levels as the traffic flow of cyclists and/or pedestrians (high or normal) is not specified by a fixed number, but the system shows even more inconsistencies for S lighting classes which makes the application almost impossible.

In the VITO study three ‘road categories’ have been defined which correspond with classes used in European statistics for road lengths. These are category F “fast traffic” for roads with fast motorized traffic only, category M “mixed traffic” for roads with motorized traffic, slow moving vehicles, and possibly cyclists and pedestrians, and category S “slow traffic” for mainly urban and pedestrian areas. In a simplified version of the European guidelines (informative technical report CEN/TR 13201-1) the road categories “F” and “M” are linked with the lighting classes ME/MEW of the European standard EN 13201-2 using some typical situations as examples. The descriptions of typical situations and the associated lighting classes ME show some dependence of the lighting levels on speed and traffic, but without consideration of all other parameters. The road category “S” is linked with the lighting classes CE and S as specified in the European standard EN 13201-2 , again using typical situations showing different lighting levels as function only of “busy, normal and few” traffic. In general these examples are almost all in contradiction to the selection procedure described in CEN Technical Report TR 13201-1. Although the layout of the table 1 in the VITO study suggests a strong influ-

ence of the traffic on the required lighting level, adaptive lighting is not considered in detail.

2.4.3 Adaptive road lighting

In 2005 the CIE Technical Committee TC 4-44 “Maintenance and Management of Road Lighting” was set up with the scope to revise the earlier CIE Publication 115 “Recommendations for the Lighting of Roads for Motor and Pedestrian Traffic” taking into account the global discussions concerning power consumption related environmental aspects; also in view of improved performance of lamps and luminaires and especially of new electronic control gear which makes it easier to introduce adaptive road lighting. As a result the final draft of the revised report CIE 115:200X entitled “Lighting of Roads for Motor and Pedestrian Traffic” is under ballot process. In this report a simple model is described for the selection of appropriate lighting classes (M for motorized traffic, C for conflict areas, and P for pedestrian and low speed areas), based on the luminance or illuminance concept, taking into account the different parameters relevant for the given visual tasks. To avoid anomalies and interdependencies as found in the European documents CEN/TR 1320 and EN 13201-2 the number of parameters had to be reduced and restructured. The lighting requirements associated with the different lighting classes – in terms of average road surface luminances, average and minimum horizontal illuminances and uniformities – had to be modified slightly (compared with the European standard EN 13201-2 in such a way that the ratios between average and minimum values are kept constant to allow for dimming. This applies in a similar way to the additional requirements for facial recognition in terms of minimum vertical or semi-cylindrical illuminances. For the evaluation of glare in conflict and pedestrian areas caused by the luminaires of adaptive lighting systems it was necessary to extent the threshold increment approach also to the C and P lighting classes. The fixed luminous intensity limits for different angles of elevation as specified in the informative annex of the European standard EN 13201-2 cannot be applied in cases of variable lighting levels as there exists no relationship between the actual lighting level (which is responsible for the adaptation level and in turn for the glare experienced) and the maximum luminous intensities.

2.4.4 Conclusion

In the VITO study *“Preparatory Studies for Eco-design Requirements of EuPs, Final Report Lot 9: Public street lighting, January 2007”* reference is being made to the E-Street project on intelligent street lighting under the heading ‘energy saving potential by light dimming’. There are four relations mentioned that justify dimming according to local conditions, i.e. dimming related to traffic volume, dimming related to weather conditions, fine tuning to adapt to local parameters (e.g. geometry, road surface), and dimming to compensate for lamp lumen depreciation. Energy savings are estimated to be between 16 % (magnetic ballast) and 22 % (electronic ballast) based on 6 hours bi-level dimming out of typical 11 hours daily operation. This possible energy saving is converted into a so-called ‘ballast gain factor’ which is used in the calculation of the annual energy consumption. The recommendations to complement the European existing documents of CEN are summarized in the VITO study as follows:

“The European standard EN 13201-2 gives only minimum requirements but no maximum light levels.”

This is true in general, but in the majority of cases the installed lighting levels will not exceed the levels prescribed following the selection procedure of CEN/TR 13201-1. For lighting classes S there is a limit (1.5 times the average illuminance required for the class) specified in the European standard EN 13201-2 for the actual average illuminance to achieve the minimum illuminance required.

“The CEN Technical Report TR 13201-1 offers no clear solution for dimming applications as it determines traffic volume on a daily bases”.

Here the revised CIE publication *"Lighting of Roads for Motor and Pedestrian Traffic, final draft of revised CIE Publication 115:200X, 2008"* offers much more flexibility not only considering traffic volume but also a number of other time dependent parameters like speed, traffic composition and/or ambient luminance.

Although in the calculation of energy consumptions temporarily reduced lighting levels (of adaptive lighting system) are taken into account (indirectly using e.g. the 'ballast gain factor'), the finally suggested bench mark values to measure energy efficiency are based on lighting power densities (LPD) only in accordance with the VITO study. For best available technologies (BAT) the values are 0.25 $W/m^2/cd/m^2$ for ME lighting classes and 0.03 $W/m^2/lx$ for CE and S lighting classes, the maximum values are 0.5 $W/m^2/cd/m^2$ for ME lighting classes and 0.06 $W/m^2/lx$ for CE and S lighting classes respectively. These values would apply to the 100 % level of adaptive lighting systems. Used as the only energy efficiency measure lighting power densities (LPD) do not offer any incentives to install intelligent controls and adaptive lighting systems. There is still a need to specify an additional energy efficiency measure based on the annual energy consumption, whether total or related to the area considered, to the lighting level, or to both. This should be the task of an appropriate CEN working group which is going to extent and/or to revise the considered European documents on road lighting including the European standard EN 13201 all parts.

3. FINDINGS FROM OTHER WORK PACKAGES

In the beginning of road lighting projects several aspects will be considered. Adaptive lighting is one of energy saving measures. Before its use following means are to be taken into account:

Existing installations
- rehabilitation of obsolete installations
- change of lamps and gears
- change of luminaires and lamps

New installations
- proper lighting class
- correct use of reliable softwares
- suitable lightdistribution properties
- maximum lm/W ratio
- avoidance of over-dimensioning
- use of adaptive lighting
- calculation of LCC costs

4. NEW RECOMMENDATIONS

4.1 International Commission on Illumination (CIE)

Report CIE 115-1995 is under revision, Technical Committee TC 4-44 will revise the publication in such a way that lighting performance requirements may vary depending on actual status of environmental and traffic conditions.

Technical committee, consisting 23 active members and 5 advisors representing 15 countries, has carefully considered the whole content of report. The committee has met several times and has prepared the final draft in March 2008 for committee ballot Divisional and Board ballot will be conducted in 2008. The report will hopefully be published during 2009.

It is also to be mentioned that five of the above mentioned committee members are active participants with E-Street project.

Compared to the existing publication the revised version gives basis for the adaptive lighting and includes practical, easily used method for selection of lighting class. This selection procedure has same parameters as in the technical report CEN/TR 13201-1. See paragraph 2.2.2.

Because the draft is in the voting stage and it is not yet accepted by the CIE Board only few subjects are presented as an example.

From the E-Street Project point of view the most important chapters are presented in the following extract from the final draft. Quotations are written in italics.

1. INTRODUCTION

1.2 Need for road-lighting

Rehabilitation of obsolete and uneconomic installations is important. It is possible to obtain higher luminance values with lower energy consumption. Upgraded lighting and control systems will often result in good cost-benefit ratios and short amortization periods.

The visual needs of road users under reduced traffic volumes during certain periods of night or under varying weather conditions, and the positive benefits of reduced energy consumption and potential environmental improvements, are some of the considerations for the installation of adaptive road lighting. There are suitable instruments, devices and methods which can be used for the intelligent control of a road lighting installation. The control systems range from very simple to the most modern applications.

6. QUALITY CRITERIA AND LIGHTING CLASSES

6.2 Selection of lighting classes

6.2.1 Normal lighting

Normal lighting is that class which is appropriate if the same level is to be used throughout the hours of darkness, selected from table. In selecting the normal class the maximum value of the selection parameters likely to occur at any period of operation should be considered, e.g. for traffic volume consider peak hourly value.
The installation should be designed to comply with all the quantitative and qualitative requirements of the selected class.
Many countries have developed valid systems to determine the appropriate normal lighting class. (CEN CR 14380:2003, CEN TR 13201-1:2004, CERTU 2007, BS 5489-1:2003 Code of practice for the design of road lighting - Part 1: Lighting of roads and public amenity areas. A system which can be used to determine the normal lighting class for motor traffic, conflict areas and road lighting for pedestrians is given.

For simplicity only the most important parameters are summarized in table 1 for ordinary motorized traffic. The descriptions of the parameters and the associated options are broad so that they can be interpreted to suit individual requirements for national recommendations. In some cases risk analysis or other consideration (environmental for example) could lead to the consideration of other parameters. When a selection is made, all road users, including motorists, motor and pedal cyclists, and pedestrians should be considered.

Examples of the selection of lighting classes using this system are given.

6.2.1 Adaptive lighting

As indicated in clause 6.2.1, the normal lighting class is selected using the most onerous parameter values, and the application of this class may not be justified throughout the hours of darkness. (This

might be under changing conditions e.g. weekends, different weather conditions) Temporal changes in the parameters under consideration when selecting the normal class could allow, or may require, an adaptation of the normal level of average luminance or illuminance, usually by reducing the level. The most important parameters in this respect are likely to be traffic volume and composition, weather conditions but ambient luminance can also have an influence.

The adapted lighting level or levels should be the average luminance or illuminance from a class or classes in the same table from which the normal class has been selected.

Table 1 can be used to select the appropriate adapted lighting class or classes for different periods of the hours of darkness when the value of the selection parameters is significantly different.

The examples of the use of the tables include the selection of the adapted lighting classes, and it can be seen that only the average level of luminance or illuminance is varied.

It is important that the changes in the average lighting level do not affect the other quality criteria outside the limits given in the system of lighting classes. Reducing the light output from every lamp by the same amount using dimming techniques will not affect luminance or illuminance uniformity, or the object contrast but the threshold contrast increases. Reducing the average level by switching off some luminaires will not fulfil the quality requirements and is not recommended.

The use of adaptive lighting can provide significant reduction in energy consumption, compared with operating the normal lighting class throughout the night.
Where the pattern of variation in parameter values is well known, such as from a record of traffic counts on traffic routes, or can be reasonably assumed, as in many residential areas, a simple time based control system may be appropriate.

In other situations an interactive control system linked to real-time data may be preferred. This approach will permit the normal class to be activated in the case of road works, serious accidents, or bad weather or poor visibility.

7. REQUIREMENTS FOR MOTORIZED TRAFFIC – THE LUMINANCE CONCEPT

The M lighting classes are intended for drivers of motorized vehicles on traffic routes, and in some countries also on residential roads, allowing medium to high driving speeds. The lighting recommendations, given in classes M1 to M6, depend on the geometry of the relevant area and on the traffic and time dependant circumstances. The appropriate lighting class has to be selected according to the function of the road, the design speed, the overall layout, the traffic volume and composition, to the environmental conditions.

For the determination of the M lighting class to be applied the appropriate weighting factors for the different parameters have to be selected and added up to find the sum of the weighting values (SWV). The number of the lighting class M is then calculated as:

Number of lighting class M = 6 - SWV

Careful selection of appropriate weighting factors will yield numbers between 1 and 6. In some cases it may be necessary to round to the nearest whole number, or to limit the range from one to six.

Table 1: Parameters for the selection of M lighting class

Parameter	***Options***	***Weighting Factor WV***	***WV Selected***
Speed	*High*	*1*	
	Moderate	*0*	
Traffic volume	*Very high*	*1*	
	High	*0.5*	
	Moderate	*0*	
	Low	*-0.5*	
	Very low	*-1*	
Traffic composition	*Mixed with high percentage of non-motorized*	*1*	
	Mixed	*0.5*	
	Motorized only	*0*	
Separation of car-riageways	*No*	*1*	
	Yes	*0*	
Intersection density	*High*	*1*	
	Moderate	*0*	
Parked vehicles	Present	1	
	Not present	0	
Ambient luminance	Very high	1	
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very low	-1	
Visual guidance / traffic control	Poor	0.5	
	Good	0	
	Very good	-0.5	
		Sum of **W**eighting **V**alues	**SWV**

The controlling criteria for the lighting of roads for motorized traffic are the luminance level and uniformity of the carriageway, the illuminance level of the surrounds of the road, the limitation of disability and discomfort glare, and the requirements for direct visual guidance. Recommended values are given in table 2 for the lighting classes M1 to M6, reflecting various traffic situations.

The lighting criteria used are the maintained average road surface luminance (L_{av}), the overall (U_o) and longitudinal (U_l) uniformity of the luminance, the surround ratio (SR), and the threshold increment (TI).
These values apply to roads which are sufficiently long so that the luminance concept can be used, outside conflict areas and/or outside areas with measures of traffic calming. The surround ratio is considered for roads with adjacent footpath/cycle path only when no specific requirements are given.

Table 2: Lighting requirements for motorized traffic, based on road surface luminance

Lighting class	Road surface luminance				Threshold increment	Surround ratio
	Dry			Wet *		
	L_{av} in cd/m^2	U_o	U_l	U_o	TI in %	SR
M1	2.0	0.40	0.70	0.15	10	0.5
M2	1.5	0.40	0.70	0.15	10	0.5
M3	1.0	0.40	0.60	0.15	10	0.5
M4	0.75	0.40	0.60	0.15	15	0.5
M5	0.50	0.35	0.40	0.15	15	0.5
M6	0.30	0.35	0.40	0.15	20	0.5

Applicable **in addition to dry condition, where road surfaces are wet for a substantial part of the hours of darkness and appropriate road surface reflectance data are available.*

Furthermore is the draft there are considered in the same way as above the following subjects:

- *lighting of conflict areas*
- *road lighting for pedestrians*
- *appearance of environmental aspects*
- *vision concept*
- *references*
- *annexes*
  - *economic calculations*
  - *road lighting under snow conditions*
  - *threshold increment*
  - *control of glare in pedestrian and low speed traffic*
  - examples for lighting classes

4.2 European Committee for Standardization (CEN)

Document CEN/TR 13201-1. “Road lighting. Selection of lighting classes” is a technical report. This is informative not a standard.

This document should be revised in accordance with the revised report CIE 115:2008. Selection of lighting class can not be standardised because the subject is depending of the national lighting and traffic safety policy as well as financial possibilities and allocation.

The German delegate in CEN/TC169 has presented the situation in CIE/TC 4-44 and E-Street project at the committee meeting 27.9.2007 in London.

The committee made the following resolution178.

CEN TC/169 agreed to re-establish the CEN/TC 169/226 JWG under the Convenorship of David Coatham with the first task to develop EN 13201-5: Energy efficiency requirements and subsequent revision of TR 13201 Part 1 and EN 13201 Parts 2-4.

5. NEW STANDARDS

5.1.1 International Organization for Standardization (ISO)

When the report CIE115:200X (cf 4.1) is approved and published CIE/Central Bureau will negotiate about the possible ISO standard.

5.2 European Committee for Standardization (CEN)

Existing standards are presented in the paragraph 2.3.2.

These standards, parts 2, 3 and 4 should be reviewed and revised, especially part 2, in accordance with the revised publication CIE 115:2008. Cf 3.1.4.3.

The Finnish delegate in CEN/TC 226 presented activities of CIE/TC 4-44 and E-Street project at the committee meeting on 14.-15.6.2007 in Oslo. The committee decided to consider the revision of standards.

This matter was treated again in the committee meeting on 12.-13.6.2008 in Milano. Committee made the following resolution 327.

CEN/TC 226 agrees to the reactivation of CEN/TC169/226 JWG and request CEN/TC169 to launch an appeal to NSB for candidate nomination(s) for a new convenor in accordance with the CEN rules.

6. GUIDELINES

6.1 Introduction

This report gives state of the art in the field of national guidelines.

Contents is based on the information from the participating countries.

Extent and accuracy of documents vary moderately. Some countries have the national lighting policy, European standards, especially EN 13201, are widely adopted. Adaptive road lighting is already mentioned in few cases.

6.2 State of the art in participating countries

6.2.1 Bulgaria

6.2.1.1 Abstract

There isn't a special National Administration in Bulgaria, responsible for road lighting and lighting policy.

The municipality of the town is the proprietor of the street lighting and it elaborates its own specific lighting policy according to the local problems and the financial possibilities.

The Executive Road Agency takes care of road lighting in Bulgaria but usually only for concrete proposals to illuminate one or another road and provide the necessary investment. There isn't a special section or team of specialists, which lay down the lighting policy.

For many years the code for street lighting was BSS 5504/1982 (Bulgarian standard for street lighting). Two years ago the European standard for street lighting BSS EN 13201/2005 was accepted – official only parts 2, 3 and 4, but part 1 is used always too. The differences between the two standards are not considerable.

The quality of lamps and luminaires have to correspond to the requirements of Bulgarian and European standards and CIE Recommendations. National standards for lamps and luminaires are harmonized with the European standards.

There is an independent control upon the projects and the realization of street lighting.

6.2.1.2 Lighting policy

Municipalities are the proprietors of the street lighting equipments in the towns.

The lighting of roads between towns is public property and the Executive Road Agency controls it in all the country.

The municipalities and the Executive Road Agency plan and invest in the construction of new lighting and refurbishment of obsolete road lighting. The maintenance of road lighting is different. In some towns private firms maintain the road lighting. In other cases, the municipality has its own service.

The street lighting is automatically switched on 30 minutes before sunrise and switched off 30 minutes after sunset. For this purpose radio control is used and in rural areas – electrical clockworks with seasonal correction. Now adaptive street lighting is very topical. A few pilot projects for will probably be realized next year.

6.2.1.3 National code of practice for road lighting

The Bulgarian standard for street lighting BSS 5504/1982 is still valid. But our designers use now only the European standard for street lighting BSS EN 13201/2005.

6.2.1.3.1 Need for road lighting

Basic parameters of street lighting:
Average luminance
Average illuminance
Overall uniformity
Lengthwise uniformity
Glare restriction (TI %)

6.2.1.3.2 Performance requirements for lighting parameters

Lighting situation is defined in conformity with type, speed and volume of traffic, as it is indicated in European standard.

Choice of lighting class is according to European Standard and CEN recommendation.

All recommendations of European Standard for dry road surface are considered.

Tables with the values of lighting requirements for motorized traffic, conflict areas and pedestrian, given in European standard are taken into account.

6.2.1.3.3 Public roads in rural areas

The lighting in rural areas is designed and implemented according to the requirements of the European Standard. The lighting class of the streets is usually ME5, ME6 or ES.

6.2.1.3.4 Roads and streets on urban areas

The beautification aspects of street lighting has become important in resent times.

The beautiful night picture of the town depends on the quality of street lighting.

That is why the contemporary trend is characterized by using " architectural street luminaires " with special design, illumination of representative avenues, boulevards, residential areas, parks and gardens, shopping areas with white light with improve color rendering.

6.2.1.3.5 Tunnels

The tunnel lighting in Bulgaria is designed and implemented according to the requirements of the European Standard for tunnel lighting. Traffic weighted L_{20} method and high-pressure sodium lamps and asymmetrical counterbeam lighting system to diminish the electricity consumption are used.

The electrical installation is defined in conformity with the recommendations in RABT – DIN 67524

6.2.1.3.6 Planning and design

- Preliminary study of the object and elaboration of assignment for design.
- First stage (level) of design: principle technical solution of all part of street lighting equipment.
- Second stage (level) – final design is based on the preliminary design. It is worked out separately for each detail of lighting equipment and describes the technical implementation of the proposed solutions in the first stage of design. It is the basic document of the activity planning for the construction.
- There is an independent control upon the projects and the realization of street lighting.

6.2.2 Czech Republic

Private companies or companies owned by municipality maintaining public lighting or "Directorate of roads and highways" has the responsibility for planning and design, in-

stallation and maintenance of road lighting. There are one basic document based on the european standard for road lighting, which is in effect since April 2007 and consits of four parts:

ČSN CEN/TR 13 201-1: *Road lighting – Part 1: "Selection of lighting classes*"
ČSN EN 13201-2*: Road lighting – Part 2: Performance requirements.*
ČSN EN 13201-3*: Road lighting – Part 3: Calculation of performance.*
ČSN EN 13201-4*: Road lighting – Part 4: Methods of measuring the light performance of installations.*

The first part standard offers further guidance on the selection of lighting classes and also specifies the lighting classes set out in EN 13201-2 and gives guidelines on the application of these classes. It is stated the way of reclassification of illuminated relevant area during different periods of the night also in different seasons of the year. Significant variation of parameter values can apply at different periods of the night, particularly in respect of ambient luminance and traffic flow.

If there is a significant change of traffic flow and/or luminance during the night, it is recommended to use proper means to reduce lighting level and so the comsumption of electrical energy. By dimming it is necessary to sustain illuminance uniformity. Reduction of lighting level might be underlaid by analysis of variation of the traffic flow on the relevant area (analysis of AHT-average hour traffic) and/or change of ambient luminance during the night (during the operation of lighting system). It is allowed to reduce the lighting level up to 50% nominal lighting level (average value of maintained luminance or illuminance) correspondig to appropriate lighting class. In the case of extreme decrease of the traffic flow, it is allowed to reduce lighting level up to 25 % nominal lighting level. Reduction of lighting level about more than 50 % nominal lighting level must be underlaid by analysis of variation of traffic flow on the relevant area and must be approved by appropriate road authority.
In the case of road lighting with increased crime risk and/or accident frequency in night time, dimming of lighting systems is not recommended.

Obtrusive light and disturbing light from outside are discussed in accordance with CEN standard.

6.2.3 Denmark

6.2.3.1 Abstract

In Denmark the European norm is published as DS/EN 13201, but local Danish recommendations from 1999 is still in force.

The L- , LE- and L- classes in the Danish recommendation corresponds to MEW ,CE- and A- classes in the European norm, but there are differences in specifications on disability glare, lengthwise uniformity and wet road uniformity

6.2.3.2 National code of practice for road lighting

6.2.3.2.1 Content

The Danish “Vejbelysningsregler, 1999”.has the following chapters

1. Introduction

2. Planning of road lighting

3. Establishing of road lighting
   3.1.1 General
   3.1.2 Motor- and motor traffic roads
   3.1.3 Traffic roads
   3.1.4 Crossings
   3.1.5 Round abouts
   3.1.7 Parths, pedestrian areas/streets and park-inlots
   3.1.8 Pedestrian crossings
   3.1.9 Speed limmiting obstructions

3.2 Roads in open land

4. The installation
   4.1 Mast geometry
   4.2 Height of masts
   4.3 Lighting of pedestrian crossings
   4.4 Luminaires
   4.4.1 Surroundings
   4.4.2 Glare
   4.4.3 Vandal classes
   4.5 Lamps
   4.6 Masts

   4.7 Lighting of surroundings
   4.8 Estetical aspects
   4.9 Optical guidance

5.. Changing of existing in-stallations
   5.1 General
   5.2 Changing of electrical installation
   5.3 Changing of light technical quality

6. Periodical dimming of road lighting

7. Annex A – Lighting classes
   Annex B - Luminaires

6.2.3.2.2 Performance requirements for lighting parameters

Requirements for motor traffic are based on luminance concept in accordance with recommendations of CIE and CEN standards. Wet surfaces must be taken into account. Illuminance concept is used on conflict areas and for pedestrian and bicycle traffic and quality control.

Example of specifications:

Belysningsklasser i L-rækken	motorveje o.l.			trafikveje o.l.				
	L1	L3	L5	L2	L4	L6	L7a	L7b
Luminanser på tør kørebane:								
Middelluminans (L_m) cd/m^2 (driftsværdi) minimum*):	2,0	1,5	1,0	2,0	1,5	1,0	0,75	0,50
Regelmæssighed (R) minimum:	0,40	0,40	0,40	0,40	0,40	0,40	0,40	0,40
Langsregelmæssighed (R_L) minimum:	0,60	0,60	0,60	0,30	0,30	0,30	0,30	0,30
Luminanser på våd kørebane:								
Regelmæssighed (R) minimum:	0,20	0,20	0,15	0,20	0,15	0,15	0,15	0,15
Synsnedsættende blænding: (TI) % maximum:	6,1	6,5	6,8	6,1	6,5	6,8	7,0	7,0
Belysningsklasse på de nærmeste 3,5 m langs kørebanen:	E1	E1	E2	E1	E1	E2	E2	E2
*) Når minimumkravet til middelluminans har stærkt uheldige konsekvenser for belysningsanlæggets udformning, og der opnås væsentlige fordele herved, kan kravet underskrides med højst 10%.								

Skema A.1. Krav til L-rækkens belysningsklasser.

6.2.3.2.3 Additional guidance documentation:

As a suplement to ”Vejbelysningsregler” a handbook on technical issues and one about eastetical aspects are published.

6.2.4 Finland

6.2.4.1 Abstract

The Finnish National Road Administration has the responsibility for planning and design, installation and maintenance of road lighting on public roads. There are three basic documents: lighting policy, code of practice for road lighting and general requirements and specifications.

Lighting policy gives general rules.

Code of practice includes eight chapters with coherent guidelines for the practical planning and design. The Third edition was published in 2006. This revised version is based on the latest CIE recommendations and CEN standards. Saving of energy, minimizing of LCC costs and the use of adaptive road lighting are emphasized.

General specifications include requirements for construction and installation works. Furthermore there are performance requirements for the adaptive road lighting.

6.2.4.2 Lighting policy

Document gives general rules:
- Owner of road lighting
- Construction of new road lighting
- Need for road lighting
- Rehabilitation of obsolete road lighting
- Maintenance of road lighting

Conditions for dimming, night-time switching off and adaptive lighting is given in this chapter

Example

Profitable traffic volumes from traffic economics point of view. Volumes are predicted numbers ten years after installation of road lighting

Road category	ADT (veh/d)		
Motorway - central reserve > 12 m - central reserve < 12 m Semi-motorway	 40 000 18 000 13 000		
	Junction density (pc/km)		
Roads in the basic network	0	2	5
Roads with central guard rail	12 000	10 000	8 000
Other main roads - cars only - all-purpose		 8 000 6 000	 5 000 4 000
Collector roads - all-purpose		 5 000	 3 000

6.2.4.3 National code of practice for road lighting

The third edition was published in 2006. Publication No TIEH 21003-v-06 (the Finnish title “Tievalaistuksen suunnittelu”) can be downloaded from web side of FinRA www.tiehallinto.fi/thohje.

6.2.4.3.1 Need for road lighting

There are six paragraphs dealing with
- effect of road lighting on the traffic safety
- light as a part of the road environment
- objects to be lighted
- economic calculations
- adaptive road lighting with intelligent control

Concept is based on the findings of E-Street project

6.2.4.3.2 Performance requirements for lighting parameters

Requirements for motor traffic are based on luminance concept in accordance with recommendations of CIE and CEN standards. Wet surfaces must be taken into account. Il-

luminance concept is used on conflict areas and for pedestrian and bicycle traffic and quality control.

Choice of lighting class is a simplified method in line with CEN recommendation. This paragraph includes also instructions how luminance can vary depending on traffic volume and road conditions in accordance with the functional and quality requirements presented in the final engineering.

Obtrusive light and disturbing light from outside are discussed in accordance with CEN standard.

6.2.4.3.3 Public roads on rural areas

Instructions for selection of the lighting solutions. Saving of energy and minimising on LCC costs are important measures. Examples of arrangements for road in different functional classes of roads, intersections, interchanges, other areas, bridges etc.

6.2.4.3.4 Roads and streets on urban areas

Basic principles as above. In addition city beautification aspects.

6.2.4.3.5 Tunnels

Instructions are in accordance with CIE and CEN recommendations. The traffic weighted L_{20} method is used.

6.2.4.3.6 Planning and design

Design tools for lighting technics, columns, foundations, electricity systems, and cost calculations.

Paragraph “Electricity systems” includes instructions for the intelligent control of the adaptive road lighting.

6.2.4.3.7 Lighting plans

Implementation of road lighting requires usually three plans of different level. They have their own goals and accuracy.

Working-out and contents of plans are presented.

Feasibility study

In the feasibility study of lighting the long-term (> 15 a) objectives and program of the road and street lighting in built-up areas, towns or urban areas are described.

Consideration of adaptive road lighting is included
- profitability of adaptive lighting
- areas and road sections to be maintained under different level of intelligent control

Preliminary engineering

This type of plan is needed for dedicated road section or for a restricted and specific area of a town, city or community. Preliminary engineering will be worked out mainly due to environmental reasons and for city beautification.

Final engineering

The final engineering of lighting is a plan which is based on the feasibility study or on the preliminary engineering or some other similar plan. The final engineering is worked out separately for each road. It is the main document of installation and describes the final result of the work. It is also the basic document of the activity planning for construction.

Document “Special specifications” describes among others for the intelligent control functional and quality requirements, equipment and components, control properties, software, tests etc.

6.2.4.3.8 Procurements

- Conventional method: separate design, construction and maintenance
- Total contract including design
- LCC method which includes financing, design, construction and maintenance

6.2.5 Germany

Selected German standards and national guidelines in the field of exterior lighting.

Road lighting

DIN 13201-1:2005 Road lighting – Part 1: Selection of lighting classes; German version of
CEN/TR 13201-1:2004

DIN EN 13201-2:2004 Road lighting – Part 2: Performance requirements; German version of EN 13201-2:2003

DIN EN 13201-3:2004 Road lighting – Part 3: Calculation of performance; German version of EN 13201-3:2003

DIN EN 13201-4:2004 Road lighting – Part 4: Methods of measuring lighting performance; German version of EN 13201-4:2003

Tunnel lighting

DIN 67524-1:2008 Lighting of street tunnels and underpasses; general quality characteristics and guide values

DIN 67524-2:1992 Lighting of street tunnels and underpasses; calculation and measurement (revision pending, 2009?)

RABT 2006 **Richtlinien für die Ausstattung und den Betrieb von Straßentunneln**

Outdoor work place lighting including parking lots

DIN EN 12464-2:2007 Light and lighting – Lighting of work places – Part 2: Outdoor work places; German version of EN 12464-2:2007

Railway lighting (exterior)

DIN EN 12464-2:2007 Light and lighting – Lighting of work places – Part 2: Outdoor work places; German version of EN 12464-2:2007 (to be applied to the lighting of platforms, approved by EBA Eisenbahnbundesamt)

Lighting of locks

DIN 67500:1987 Illumination of lock areas; requirements, design and measurement

Lighting of pedestrian crossings

DIN 67523-1:1988 Lighting of pedestrian crossings (sign 293 StVO) with additional lighting; part 1: general quality characteristics and guide values

DIN 67523-2:1988 Lighting of pedestrian crossings (sign 293 StVO) with additional lighting; part 2: calculation and measurement

R-FGÜ 2001 **Richtlinien für die Anlage und Ausstattung von Fußgängerüberwegen**

Obtrusive lighting

DIN EN 12464-2:2007 Light and lighting – Lighting of work places – Part 2: Outdoor work places; German version of EN 12464-2:2007 (evaluation of TI on nearby traffic routes)

Licht-Leitlinie 2001 **Leitlinie des Ministeriums für Landwirtschaft, Umweltschutz und Raumordnung zur Messung und Beurteilung von Lichtimmissionen (veröffentlicht im Amtsblatt für Brandenburg, kommt in allen Bundesländern zur Anwendung beim Vollzug des Bundes- und Landesimmissionsschutzgesetzes)**

6.2.6 Ireland

6.2.6.1 Lighting Policy for National Roads and Motorways (Draft)

In normal circumstances, lighting should be provided at the following locations:

1. Inside an Urban Area:

- ie speed limit 60 km/h or less. This does not include lighting where periodic special speed limits are in place eg. at schools

2. At-Grade Junctions:

- At roundabouts
- At junctions with raised islands
- At-grade junctions on dual carriageways where there is a median break for use by turning traffic
- At junctions where the mainline flow > 12,000 and the sideline flow > 3,500

Junctions on 2 plus 1 roads should not be treated differently – lighting should depend on junction type and flows as outlined above.

Where developments on side roads result in the thresholds being exceeded, the cost of providing lighting should be covered by the developer.

Retrofit of the existing network should be carried out.

For new schemes, where the traffic flows will not exceed the thresholds at year of opening, but are expected to exceed the thresholds within 10 years, then ducting should be provided during scheme construction.

3. Motorways / High Quality Dual Carriageways:

At grade separated interchanges:

The mainline should be lit from the start of the diverge taper to the end of the merging manoeuvre – approximately 100m past the end of the merge taper. The slips should also be lit, along with the junctions of the slip roads with the side road(s).

Where there is only an off-slip:
The mainline should be lit from the start of the diverge taper to 50m after the end of the diverge nose. The slip should also be lit, along with the junction of the slip with the side road(s).

Where there is only an on-slip:
The mainline should be lit from 215m back from the start of the merge nose to 100m after the end of the merge taper. The slip should also be lit, along with the junction of the slip with the side road(s).

UK (and Ireland) DMRB
BS 5489-1:2003
8.3.3 Lighting for slip roads:
Where slip roads connect two levels of road, particular attention should be given to the following:
View of the rising slip road from both the upper and lower levels
Clear definition of routes and turn-off points
Clear revealing of merging traffic

Light between **lit interchanges** when the distance between them < 1.5 km

4. Apart from the above, lighting will not normally be provided, except:

- Where there is an above-average history of night time accidents, and an examination of the crash history at those locations indicates that improved lighting should reduce the possibility of collisions.

6.2.6.2 National code of practice for road lighting

Design of lighting is carried out in accordance with BS 5489 parts 1 and 2. In addition following aspects are to be taken into account:

- Consistency of lighting within the scheme and with the adjacent network
- Safe positioning of lighting columns, signals and operational equipment
- Confusion or conflict between lighting and traffic signals
- Positioning of heads for traffic and pedestrian signals to ensure clarity to appropriate road user, and avoid confusion to others to whom they do not apply
- Safe access and servicing arrangements

6.2.7 Netherlands

6.2.7.1 Abstract

The Dutch National Road Administration (Rijswaterstaat) has the responsibility for planning and design, installation and maintenance of road lighting on public roads. The provinces and Cities all have their won repsoibilities. There are three basic documents used and often referred to: Verlichting Openbare Ruimte, Nederlandse Praktijk richtlijn (NPR 13201-1) and the Handboek Dynamische Verlichting.

Handboek Openbare Verlichting gives general rules on Public Lighting.

The Handboek gives guidelines for the practical planning and design of outdoor lighting systems. The newest edition was published in 2007. This revised version is based on the latest CIE recommendations and CEN standards as well as the NPR. Saving of energy, minimizing of LCC costs and the use of adaptive road lighting are emphasized but not described on the sense of Dynamic Lighting Systems although they are mentioned.

General specifications include requirements for construction and installation works as well as directives for lighting design.

All cities and provinces have their own policy document and their own vision on how to do public lighting. Because of this it is hard to describe any of these “sub” documents because there are just too many of them.

6.2.7.2 Verlichting Openbare Ruimte (Lighting of public areas)

Document gives discusses the different parts of the outdoor lighting system in relation to the following factors:

- Energy
- Environment
- Light Pollution

The document lists the different parts of the system and does recommendations for them when it comes to luminaires, lamps, electronics, poles, cables and maintenance of the solutions . There is an extensive part about the legal aspects, rules and regulations and the pro’s and con’s of outdoor lighting.

There are several links in the document to other publications when it comes to LED, and other light sources.

6.2.7.3 Nederlandse Praktijk Richtlijn (NPR 13201-1) (Practical Dutch Guidelines)

In the Netherlands there are no formal rules and regulations the government has to comply with. However in General it is safe to say that most city policies act according to the NPR what is a normalization document based on European directives.

In the NPR the lighting and road classes are defined based the visual needs of people using the road in various transportation modes. The requirements are related to the various technical aspects of road users and behavior under different circumstances.

In a separate chapter there is a discussion about ethical aspects, light comfort and environmental issues in relation to outdoor lighting and safety.

In the appendix there is a lighting classification explanation.

6.2.7.4 Handboek Dynamische Verlichting (Handbook for dynamic lighting)

This handbook is published but the Dutch road authorities and give a very comprehensive overview of the possibilities, requirements and regulations with regards to Dynamic Outdoor Lighting systems for the Dutch road authorities.

The handbook describes:

6.2.7.5 System architecture

In this chapter the complete systems architecture of a Dynamic Outdoor Lighting (DOV) system is explained. It goes into detail on Lamp Controllers, Segment controllers and management software. The handbook gives very detailed specification for the DOV solution components.

6.2.7.6 Systems functions

The system functions chapters givens a detailed description of all the functions a Dynamic Outdoor Systems should deliver to the various system beneficiaries. It talked about constant light levels, virtual lamp power, dimming capabilities and alarming.

6.2.7.7 Systems interfaces

This part of the document describes how the solutions should communicate with the other existing traffic management systems and what should be the result of this communications. This part also discusses the various possibilities and restriction for communications over the Dutch VIC net what is the network for Road related communications in the Netherlands.

6.2.8 Northern Ireland

http://www.roadsni.gov.uk/index/whatwedo/whatwedo-street_lighting.htm

6.2.8.1 Lighting policy

Roads Service is responsible for street lighting on public roads and streets across Northern Ireland.
In April 2007, the number of street lights was just over 261,000.

- Street lights are provided mainly to improve road safety at night, but we know that they also help to reduce crime and the fear of crime, and to enhance the night-time urban environment
- Generally, all roads, car parks and footpaths adopted (owned) by Roads Service in urban areas are lit
- Rural roads are not usually lit unless there is a community of at least 10 houses along a 200-metre stretch, or a history of night-time road collisions
- The street lights in new housing developments are installed by the building developer during construction of the roads
- Roads Service is responsible for maintaining streetlights. On new housing developments, we adopt and maintain the lights after the developer has done the necessary certification of the new system and requested handover to us.
- We inspect street lights at night, every fortnight in winter and every 4 weeks in summer, to identify any that are not working properly
- Our maintenance work is carried out by Roads Service personnel and private contractors
- We aim to have at least 98% of street lights working normally at any one time

- We also aim to repair faults within 10 working days of discovery, unless the fault is due to the electricity supply and repair depends on the response of the supply company
- We have an annual programme of replacing old deteriorating columns
- We spend approximately £17 million per year on electricity charges and maintaining and replacing street lights
- We aim to minimise light pollution and conserve energy by using efficient lanterns for new and replacement lighting schemes.
- Roads Service is not responsible for security lighting to NIHE or housing association houses, or to council parks

6.2.9 Norway

6.2.9.1 Lighting policy

In Norway the CEN publication EN 13201 part 2-4 is published as a norm as NS/EN 13201 2-4.

Further on the Norwegian Public Roads Administration, "Statens Vegvesen", publishes it's own standards and regulations that depends on the NS/EN 13201. For roadlighting there are three publications that are most relevant;

017 - Handbook for Road- and Street-design.
237 - Handbook for Road- and Street-light.
264 - Handbook in technical planning of Road- and Street-lighting.

6.2.9.2 National code of practice for road lighting

The Norwegian Public Roads Administration guidelines are downloadable from their website at www.vegvesen.no .

The two publications Handbook 017 and handbook 264 are newly revised and are currently going through an approval process in the Ministry, but are published as a preliminary draft until it is approved. Handbook 237 was published in 2002.

6.2.9.2.1 Need for road lighting

The national guidelines in "Handbook 017" states that the MEW classes are to be used for roads with speed limit above 40 km/h, for roads with speed limit of 30 km/h and conflict areas the CE-classes are to be used for footpaths, bicycle paths and other areas separated or alongside the driving path (including parking lots and schoolyards) the S-class are to be used.

The 017 also states at what traffic situations we are to consider lighting the road. This recommendation is based on the presence of physical separation of the carriageways and traffic-flow. The recommendation is shown below in table.

ADT	**<1500**	**1500-4000**	**4000-8000**	**8000-12000**	**> 12000**
Separated carriageways		**MEW3**	**MEW3**	**MEW3**	**MEW3**
Not separated carriageways	**MWE4**	**MEW3**	**MEW2**	**MEW2**	**MEW2**

6.2.9.2.2 Performance requirements for lighting parameters

The “Handbook 263” gives the more detailed demands for the streetlighting. Requirements for motor traffic are based on luminance concept. Illuminance concept is used on conflict areas and for pedestrian and bicycle traffic. Basically road surface “C2” are to be used for light-calculations with W4 used for the overall uniformity. The table below shows the recommended lighting levels for the respective lighting classes.

Average luminance cd/m2		**2**	**1,5**	**1**	**0,75**	**0,5**			
Class	**CEO**	**MEW1 CE1**	**MEW2 CE2**	**MWE3 CE3 S1**	**MWE4 CE4 S2**	**MWE5 CE5 S3**	**S4**	**S5**	**S6**
Average illuminance lux	**50**	**30**	**20**	**15**	**10**	**7,5**	**5**	**3**	**2**

6.2.9.2.3 Lamps

The latest guidelines opens for the possibility to lower the level of lighting with 10 % if you are using Metal Halide lamps instead of High pressure sodium lamps, based upon the latest research results concerning mesopic vision. Decisions between lamps are set as an economical issue based upon LLC calculations (if all other requirements concerning quality are fulfilled).

6.2.9.2.4 Adaptive lighting

Every new installation is to be evaluated based upon their energy efficiency, if adaptive lighting is a costly effective measure it is to be implemented. Electronic ballasts are to be used in every situation where the technology is available, if electronic ballasts are installed they are to be supplied with the ability to be dimmed based on an “open platform” of communication. This secures that dimming can be implemented on a later stage without replacement of the luminaries.

6.2.10 Poland

6.2.10.1 Procedures of management of street lighting in Poland

Poland is one of the countries that took enormous effort to restructure economy from the centrally commanded model to a market one that would guarantee efficiency and prosperity to citizens. But Poland is also a very specific country when considerations of the socio-psychological circumstances are to be taken into account because they strongly influence the transformation of the sector which has been playing a significant role in the economic and social dimension of the functioning of society. In Poland the energy market has not yet fully developed. It has just launched and the process of shaping and improvement is still ongoing.
Here in Poland we have no a uniform lighting policy of all country.

At present in Poland here are the several legislation acts regarding in some parts of street lighting.

- Act of 10 April 1997 – Energy Law (Dziennik Ustaw of 2003, No 153 item 1504 and No 203, item 1966, and of 2004, No 29, item 257, No 34, item 293, No 91, item 875, and No 96, item 959, and No 173, item 1808)

- Regulation by the Minister of Economy of 23 April 2004 concerning detailed principles for setting and calculating tariffs and settlement principles in electricity trading, (Dziennik Ustaw of 2004, No 105, item 1114.
- Act of 13 November 2003 No. 203, item 1966 concerning of the earnings of local authorities

The Energy Law Act that was passed by the Polish Parliament almost ten years ago obliged the President of the Energy Regulatory Office to report annually to the Minister of Economy and inform the public opinion on the regulatory activity. This custom stemming from the experience of the countries that are much more advanced in the implementation of the market rules into the energy sector was adopted with the aim to achieve two goals. Firstly, reporting – according to the rule of transparency – was to identify the object of regulation, tools in use and their scope, but most of all – the results achieved. Secondly – it was to justify public expenditures on energy regulation.
The current set of regulatory tools for promoting energy effectiveness and competition seems to be insufficient. In fact the procedure of extracting information pertaining to energy effectiveness of the machines applied by producers and importers usually boils down to proceedings connected with applying a financial penalty resulting from the control conducted by the Trade Inspection. Due to the fact that by 17 May 2008 the Member States are obliged to implement Directive 2006/32/EC on energy end-use efficiency, the range of tasks and tools available to the President of the ERO, as well as other authorities and institutions should be fundamentally modified.
Some kind of influence for the street lighting legislation development in Poland has the Polish Committee on Illumination http://www.ee.pw.edu.pl/CIEPoland/.
At the country level this is technical - scientific association of the Polish electricians. At the international activity this is The Polish National Committee member of CIE. The main role of this committee is to give a opinion regarding the European lighting standards, to translate it and to prepare assessments for parliamentary commissions.

Professional street lighting should fulfill the base needs of the inhabitants in Poland. Management of street lighting in the towns and regions (gminas - 2560) in Poland generally is hold at the following aspects:
- exploitation / conservation
- modernization
- new installations

All new reconstruction and updating street lighting works in Poland are hold on according to European Standard EN-13201.

6.2.11 Portugal

6.2.11.1 Need of road lighting

The main propose of road lighting is to ensure the regular activities of pedestrians and vehicles, in particular when the natural light is insufficient, and within the minimal security and comfort conditions.
For drivers, it is important to perfectly distinguish and locate all the details, within the appropriate time, in particular, the direction, limits and accesses of the road and also the possible obstacles. On the other hand, for pedestrians it is essential to have a perfect visibility of the sidewalk limits, of vehicles and obstacles, and to have absence of shaded areas.

6.2.11.2 Lighting classes

In Portugal, outdoor lighting installations are grouped by classes (A, B and C), depending on the characteristics of each road, the nature and the importance of traffic and the frequency of pedestrians:

CLASS A:

Lighting for main roads, with fast and intense traffic, for which it is important to have in mind questions related with security, speed and comfort conditions during traffic circulation.

CLASS B:

Lighting for important roads, with significant flow of vehicles and pedestrians and for which it is important to have in mind, besides the vehicles circulation, also the interests of pedestrians and local stores and, also, urban aesthetics.

CLASS C:

Lighting for residential areas, mainly local traffic and with minor importance.

The classes A and B are divided in two subclasses, 1 and 2, according to the importance of the road. Table 1 establishes the link between the outdoor lighting installations and the type of roads. The presented recommendations concern mainly the lighting plan for major routes and other roads of relevant importance.

6.2.11.3 Performance requirements

Table 1 includes the recommendations, regarding the level and uniformity of luminance, the degree of glare, and the types of luminaires preferred or admitted for each type of outdoor lighting installation. For instance, Class A corresponds to the highest level and uniformity of luminance, while glare should be strictly reduced. However, Class B can include higher tolerance, in what regards the level and uniformity of luminance and glare, what can be easily justified by the particular character of arteries and, specially, the presence of facades.
The figures presented in Table 1, correspond to average values of exploitation, and for that, the depreciation of the installation is considered. The lifetime of lamps and the cleaning level of the luminaires should in fact be considered. In general, if is considered a regular maintenance, the figures presented in Table 1 correspond to 75% of the initial figures, that is, the outdoor lighting project of an installation has to start with values 1,33 times superior to those presented here.
These conclusions are the result of static and dynamic experiments, and are considered necessary and justified by the requirements of safe vision of drivers.

Table 1 – Recommendations for road lighting in different types of roads.

<table>
<tr><th>Class of the outdoor lighting installation</th><th colspan="2">Type of road</th><th>Average level of illuminance in wet pavement [cd/m^2]</th><th>Uniformity of luminance in wet pavements</th><th>Glare</th><th colspan="2">Type of luminaries</th></tr>
<tr><td>A1</td><td colspan="2">Highways</td><td rowspan="2">2</td><td rowspan="2">Very good</td><td rowspan="3">Strictly reduced</td><td>Preferred</td><td>Accepted</td></tr>
<tr><td>A1</td><td rowspan="3">Roads in open field</td><td>Intense traffic</td><td rowspan="2">Limited distribution (Cut-off)</td><td rowspan="2">Semi-limited distribution (Semi cut-off)</td></tr>
<tr><td>A2</td><td>Considerable traffic</td><td>1</td><td>Good</td></tr>
<tr><td>-</td><td>Reduced traffic</td><td colspan="5">Without outdoor lighting system</td></tr>
<tr><td>A1</td><td rowspan="3">Urban roads</td><td>Ring roads</td><td>2</td><td>Very good</td><td>Reduced</td><td>Limited distribution (Cut-off)</td><td>Semi-limited distribution (Semi cut-off)</td></tr>
<tr><td>B1</td><td>Main arteries (local traffic)</td><td>1</td><td>Good</td><td rowspan="2">Moderated</td><td rowspan="2">Limited or semi-limited distribution (Cut-off or semi cut-off)</td><td rowspan="2">Non limited distribution (No cut-off)</td></tr>
<tr><td>B2</td><td>Secondary streets (local traffic)</td><td>0,5</td><td>Satisfactory</td></tr>
</table>

6.2.12 Slovenia

In Slovenia there is a distinction between roads in responsibility of state and between roads and streets in responsibility of particular municipalities.

Roads in responsibility of the state are further devided to:

- highways (in responsibility of National Highway Authority)
- other main roads (in responsibility of National Road Administration)

Concerning road lighting there is no common policy or practice where to apply road lighting. There are some studys giving general guidance for example for highway junctions, but officially there is no exact requirement.

Common to all types of road lighting is, that where road lighting is applied, it has to be designed according to EN 13 201 (in Slovenia SIST EN 13 201).

Other general guidance is given in Recommendations of Slovene Lighting Association for Road lighting. The recommendations are mostly consistent with EN 13201.

Road lighting in municipalities: every municipality is responsible for the road lighting at its own area and creates local policy in local documents.

Where lighting is applied, it shall conform to the requirements of SIST EN 13201.

The other local document dealing with road lighting is national law called “Requirements for the limitation of obtrusive light” in force since september 2007. This law was prepared by non experts, it is obsolete, because in public lighting it enforces the solutions which are more energy demanding. But lighting designers through the country have to respect the requirements of this document.

6.2.13 Sweden

6.2.13.1 Abstract

In Sweden the Swedish Road Administration has the responsibility for planning and design, installation and maintenance of road lighting on public roads. The municipalities have the same responsibility for local roads / streets within city centers.

Guidelines for design of roads and streets are presented by Swedish Road Administration and the Swedish Association of Local Authorities and Regions (Kommunförbundet) in collaboration.

The guidelines are called VGU (VV Publication 2004:80) and replace both VU94 (general advises for national roads) and ARGUS (general advises for streets).
VGU covers most aspects on street- and roadlighting. In some cases it also refers to other publications.

The main purpose of VGU is to increase the safety for pedestrians and cyclists.

6.2.13.2 Lighting policy

6.2.13.2.1 General

National roads are owned and maintained by the Swedish Road Administration. All local roads in cities are owned and maintained by the municipalities.

New guidelines for design of roads and streets are presented by Swedish Road Administration and the Swedish Association of Local Authorities and Regions (Kommunförbundet) in collaboration.

The guidelines are called VGU (VV Publication 2004:80) and replace both VU94 (general advises for national roads) and ARGUS (general advises for streets). The purpose of this publication is to increase the safety for pedestrians and cyclists. It is based on the European standards, SS-EN 13201 and SS-EN 13201-2.

In VGU chapter 7 is dedicated to road and street lighting. The chapter describes for example as follows:

- Valid laws and regulations
- Adaption to environmental conditions
- Principal design of lighting installations, fittings, light sources, poles
- Guidelines regarding lighting design

Rehabilitation, maintenance issues is not discussed in the publication.

Principles for night-lighting and dimming are briefly covered.

6.2.13.2.2 City of Göteborg

In Sweden the guidelines from Swedish Road Administration are generally adapted but when it comes to the next level, the cities and municipalities, local policies and guidelines for implementation can be a bit different.

Traffic & Public Transport Authority, Göteborg has decided to work for a cost-effective investment in energy efficiency together with a way to use the light to make people in the community to see lighting in a new creative way that makes them feel secure.

Göteborg has its own local guideline, TPU. TPU stands for planning and installation of infrastructure. It is also valid for lighting equipment in order to help and guide involved staff eg. architects, engineers etc. In addition, Göteborg has initiated a number of plans to save energy, environment and reduce cost.

Plan for lamp sources

- Started 10 years ago changing lamp sources from mercury lamps to high pressure sodium and in the public areas to metal halogen

Plan for power reduction

- Started two years ago so between 22.00 to 05.00 are all the luminaires from 70 W and upward reduced

Plan for adaptive lighting in Göteborg

- Overall strategy for the town in the future/looking to different solutions through pilot projects starting in 2007 with two main streets (total 270 luminaires) continuing during 2008 with three new main streets (total 250 luminaires)

Development plan for adaptive lighting in Göteborg

- There is now planning in progress for adaptive lighting to get benefits for different events in Göteborg such as the yearly event “Julstaden” at Christmas but also for different sports event

- Plan for maintenance
- Exactly planned maintenance activities
- More efficient and less replacement
- Long term investment goals
- Open and flexible systems, possible to adopt to new demands, with longer lifetime

6.2.13.3 National code of practice for road lighting

6.2.13.3.1 Need of road lighting

General

Effect of road lighting on the traffic safety

- In the VGU publication it is described estimated relations between installed lighting and accidents in darkness.

Lighting as a part of the road environment and objects to be lighted

- Briefly described in VGU, as adoption to environmental conditions

Economic calculations

- National recommendations for economic calculations are not covered by VGU today. Although, during the work with VGU, economic calculations including traffic

safety aspects etc. to find out the traffic limits for different roads, motorways, dual carriageways among others was done. But we have not shown the calculations in the document.

Adaptive road lighting
- In VGU only described in general terms as power reduction in lighting installations.

City of Göteborg

Effect of street lighting on the traffic safety
- Traffic & Public Transport Authority, Göteborg is having a dialogue with Swedish Road Administration how to evaluate the effect of using Adaptive lighting on two of our main streets in Göteborg (Högsboleden and Tuveleden/ total 270 luminaires) for safety

Lighting as a part of the street environment
- Tests of Adaptive lighting on five different streets in Göteborg to evaluate visibility, atmosphere and environmental aspects during day and night and variations of year (total 520 luminaires)

6.2.13.3.2 Performance requirements for lighting parameters

This is described in VGU (VV Publication 2004:80).

Roads and streets for motorized traffic
- According to SS-EN 13201
- Luminance concept is used on roads and highways
- Illuminance concept is used in conflict areas as commercial streets, crossings, roundabouts and in areas also used by pedestrians and cyclists
- Recommendations are presented in VGU (VV Publication 2004:80), table 2-2, 2-3, 2-4 and 2-5

Roads for pedestrians and cyclists
- According to SS-EN 13201-2
- Recommendations are presented in VGU (VV Publication 2004:80), table 2-6, 2-7, 2-8 and 2-9

6.2.13.3.3 Public roads on rural areas

This is described in VGU (VV Publication 2004:80).

Recommendations of lighting in rural areas are described in chapter 3. The need of lighting is considered according to
- Traffic volume
- Specific installations on the roads, eg. roundabouts, crossings, ferry berths, tunnels
- Places with a high number of accidents in darkness
- Places with a lot of light disturbance

6.2.13.3.4 Roads and streets on urban areas

This is described in VGU (VV Publication 2004:80).

Recommendations of lighting in urban areas are described in chapter 4. Normally lighting is recommended in all urban areas. The lighting should be applied according to traffic situation, users (both traffic and pedestrians/cyclists) and needs of beautification.

6.2.13.3.5 Tunnels

This is described in VGU (VV Publication 2004:80).

Recommendations of lighting in tunnels are described in chapter 6. The lighting is divided into an number of categories:

- Night-time lighting (according to the same principles as road lighting)
- Day-time lighting (adapted to luminance levels of daylight)
- Emergency lighting (optimized for an evacuation of the tunnel)
- Stand-by lighting (in case of power failure)

6.2.13.3.6 Planning and design

General

Laws and regulations applied in Sweden are described in VGU (VV Publication 2004:80).

All materials in lighting installations should be designed and installed according to valid laws and regulations and fulfill Swedish norms for testing equipment.

City of Göteborg

Traffic & Public Authority, Göteborg is member of an organization, LUCI which is a network between 80 different cities working for better city beautification.

The work with LUCI is organized around four topics

- Environmental questions
- Architecture/lighting design
- City lighting plans
- Strategy/development for the future when it comes to lighting

6.2.13.3.7 Lighting plans

General

Implementation is described in VGU (VV Publication 2004:80), chapter 7. It covers a number of issues like:

- The purpose of using lighting
- Adaption to environment
- Light orientation
- Technical issues like recommendations when choosing fittings, bulbs

A number of municipalities in the country have according to the national directives above formed their own lighting plans for a city or a specific area.

City of Göteborg

A lighting plan is under construction for Göteborg including guidelines for lighting in the city including streets, parks, squares etc.

In the lighting policy for the city there are intensions to avoid too much light and get more light where it is needed and requested. In addition, a plan will be established for open air areas taking into consideration the need of a plan for the lighting in the centre of Göteborg after dark. It is important to know how people transport themselves after dark to make this an issue when the plans are worked out.

Feasibility study

In order to analyse the viability of adaptive road lighting a number of pilot project have been realized. The initiators have in most cases been the Swedish Road Administration or bigger cities / municipalities.

There is also a forum for consultation between representatives from Stockholm, Malmö, Göteborg, Västerås, Sundsvall and the Swedish Road Administration. This forum arrange meetings twice a year in order to exchange experiences regarding road- and street lighting.

In addition to these activities the Authority is continuously testing equipment from different manufacturers in order to evaluate possibilities to save energy, reduce maintenance and to use light in new ways within the city area.

Preliminary engineering

Same principles as described in the paragraph 2.11.3.7 are followed.

Final engineering

Today there are no specific national guidelines regarding intelligent control / adaptive lighting. Normally a specification is defined covering the control system for such an installation. This specification is today established by the responsible authority. A specification shall at least contain the following parts:

- General requirements / system design
- Technical requirements, both local and central systems
- Functional requirements, both local and central systems
- Performance requirements, both local and central systems
- Design procedure
- Quality assurance and control requirements
- Documentation requirements
- Maintenance requirements
- Training requirements

6.2.13.3.8 Procurements

A lighting installation is normally bought by a Contractor as a total contract according to the rules of public purchasing. In most cases both design, installation and maintenance through the warranty period is included in the contract price.

6.2.14 United Kingdom

6.2.14.1 General guidelines

While local authorities in the UK used to have individual lighting polices, these have all fallen by the wayside. Most now use the technical documents issued by the ILE (Institute of Lighting Engineers), there is:

TR24 – “A practical guide to the development of a public lighting policy for local authorities.”
TR23 – “Lighting of Cycle Tracks.”
TR27 – “Code of practice for variable lighting levels for Highways.”
TR25 – “Lighting for traffic calming areas.”

6.2.14.2 British standards

All above mentioned refer back to BS5489 – 2003 and BS EN 13201 – 2004 which deal with the relevant design criteria.

BS 5489 and BS EN 13201 were published on 11th December 2003, and have now
established themselves as well structured, well used standards which provide competent Lighting Engineers with the guidance and tools to design good quality,
safe lighting schemes.

6.3 Proposals for development

Guidelines are generally worked out on the national level. Outlines, content and accuracy are depending on road keeping process of the country.

However some common rules and justifications may be considered and recommended.

1. General grouping
    - Lighting policy gives general rules
    - Code of practice includes coherent guidelines for the practical planning and design
    - General specifications include performance and quality requirements for construction and installation works.
2. Planning and design process
   In accordance with the countries road planning process lighting should be treated in three stages:
    - Feasibility study includes long-term objectives and program.
    - Preliminary engineering is a plan for a dedicated road section on for a restricted and specific area.
    - Final engineering plan for construction and installation describes the final result of work.

7. PRESENTATIONS

7.1 Goal

The aim of presentations and workshops is to advise and convince standardization institutes, highway authorities, cities and municipalities to understand the meaning and use of adaptive road lighting as an energy-saving countermeasure.

7.2 Previous Activities

CIE

In accordance with the paragraph 4.1 activities within CIE TC 4-44 are nearly completed.

ISO

When the report CIE 115:200X is approved and published CIE CB will negotiate about the possible ISO standard.

CEN

In CEN/TC 169 and 226 most of European standard institutions are represented: AFNOR, BSI, DIN, DS, IBN, SN etc. In the same way several representatives of national highway authorities participate especially in TC 226. Situation is described in paragraph 5.2.

7.3 Future activities

Special workshops for standard institutions are not needed, because the real work for revision is already commenced.

On the national level there is the need to convince local authorities to understand meaning of the adaptive lighting, e.g. in Finland civil servants of cities and municipalities. FinNRA has already installed adaptive road lighting on five projects.

7.4 Seminars and Congresses

7.4.1 Previous events

PROMILL – Promoting Illuminating Engineering Studies, Research and Continuing Co-operation between Europe and China - Lecture and Training Sessions on Road Lighting Measures
April 11.-12. 2006, Fudan University, Shanghai
Pentti Hautala
Intelligent road lighting
Audience 45 persons (20 students and 25 representatives of industry)

Co-operation group UV7

UV7 is the co-operation group between six biggest city electricity companies and the Finnish National Highway Administration dealing with outdoor lighting matters.

General presentation and information of E-Street project by Pentti Hautala. Meeting in Espoo, Finland 16.5.2006, participation of 15 delegates.

I**nternational Conference**
URBAN NIGHTSCAPE 2006
Athens 21.-23.9.2006
Henri Juslen, Pentti Hautala et al
Experiences of the intelligent road lighting
Audience 120 persons

E-Street Mini-Conferencies Intelligent Street Lighting
Frankfurt 8.4.2008
Pentti Hautala
Adaptive road lighting in Finland
Audience 30 persons, mainly manufacturers

Finnish Association of Municipal Technology
Session of Municipal Technology
Espoo 5.-7.6.2008
Pentti Hautala
Adaptive Street Lighting
Audience 300 persons, mostly from cities and municipalities

7.4.2 Coming events

Accepted papers to be presented

Finnish Road Association
Conference of Traffic and Routes
Tampere 8.-9.10.2008
Pentti Hautala
Adaptive Road Lighting
Expected audience 900 persons, representatives of Highway Administration, cities and municipalities, consultants, contractors.

nordic LIGHTING + DESIGN conference
Helsinki 1.-3.10.2008.
Erik Bjelland, Penttti Hautala, Ingemar Johansson, Tor Mjös.
Adaptive road and street lighting in the Nordic countries.
Expected audiency 200 persons.

7.4.3 Sessions at call for papers stage

Illuminating Engineering Societies of Denmark, Finland, Island, Norway and Sweden

Turkish National Committee on Illumination
Lux Europa 2009

Istanbul 9. – 11.9.2009