



„Adaptive Road Lighting“
according to CIE Publication 115:200X
**„Lighting of Roads for Motor
and Pedestrian Traffic“**

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Adaptive Road Lighting



Adaptive road lighting is defined as lighting provided **where and when** it is needed **dependent on different variable conditions**, such as speed, traffic volume and/or composition, ambient luminances, weather etc.

NOTE (CIE 115:200X):

Changes of the average lighting level should not affect the other quality criteria more than prescribed in the system of lighting classes.

Lighting Classes in CIE 115:200X



There are three different sets of lighting classes in CIE publication 115:200X from which appropriate **lighting quality criteria / requirements** can be selected:

M Lighting classes for **m**otorized traffic

C Lighting classes for **c**onflict areas

P Lighting classes for **p**edestrian and low speed traffic areas

Selection of Lighting Situation, Influencing Parameters in general



- Speed (composition of users in the same relevant area)
- Geometry (separation of carriageways, type of junctions, intersection density, conflict areas, measures for traffic calming)
- Traffic use (traffic flow of vehicles, cyclists, pedestrians, parked vehicles, crime risk / facial recognition, difficulty of navigational task)
- Environmental influences (complexity of visual field, ambient luminance, weather type, colour rendition)
- Visual guidance, traffic control

Selection of **M** Lighting Class (CIE 115:200X), Parameters for Motorized Traffic



- Speed: high or moderate
- Traffic volume: very high, high, moderate, low, or very low
- Traffic composition: motorized only, mixed, or mixed with high percentage of non-motorized
- Separation of carriageways: no or yes
- Intersection density: high or moderate
- Parked vehicles: present or not present
- Ambient luminance: very high, high, moderate, low or very low
- Visual guidance, traffic control: poor, good, very good

Parameters for the Selection of a Lighting Class **M** for Motorized Traffic (CIE 115:200X)



Parameter	Options	Weighting Value 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, high percentage of non-motorized	1	
	Mixed	0.5	
	Motorized only	0	
Separation of carriageways	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 Weighting Values	SWV

Parameters for the Selection of a Lighting Class **M** for Motorized Traffic (**example**)



Parameter	Options	Weighting Value WV	WV selected
Speed	High	1	1
	Moderate	0	
Traffic volume	Very high	1	1
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic composition	Mixed, high percentage of non-motorized	1	0
	Mixed	0.5	
	Motorized only	0	
Separation of carriageways	No	1	0
	Yes	0	
Intersection density	High	1	0
	Moderate	0	
Parked vehicles	Present	1	0
	Not present	0	
Ambient luminance	Very high	1	0
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very low	-1	
Visual guidance, traffic control	Poor	0.5	0
	Good	0	
	Very good	-0.5	
Number of Lighting Class M = 6 – SWV		Sum of Weighting Values	SWV = 2

M Lighting Classes (CIE 115:200X)



LIGHTING CLASS	dry			wet *	TI in %	SR
	L_{av} in cd/m^2	U_o	U_l	U_o		
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 where road surfaces are wet for a substantial part of the hours of darkness and appropriate road surface reflectance data are available

Lighting requirements for motorized traffic

Parameters for the Selection of a Lighting Class **M** for Motorized Traffic (modified example)



Parameter	Options	Weighting Value WV	WV selected
Speed	High	1	1
	Moderate	0	
Traffic volume	Very high	1	-1
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic composition	Mixed, high percentage of non-motorized	1	0
	Mixed	0.5	
	Motorized only	0	
Separation of carriageways	No	1	0
	Yes	0	
Intersection density	High	1	0
	Moderate	0	
Parked vehicles	Present	1	0
	Not present	0	
Ambient luminance	Very high	1	0
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very low	-1	
Visual guidance, traffic control	Poor	0.5	0
	Good	0	
	Very good	-0.5	
Number of Lighting Class M = 6 – SWV		Sum of Weighting Values	SWV = 0

M Lighting Classes (CIE 115:200X)



LIGHTING CLASS	dry			wet *	TI in %	SR
	L_{av} in cd/m^2	U_o	U_l	U_o		
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 where road surfaces are wet for a substantial part of the hours of darkness and appropriate road surface reflectance data are available

Lighting requirements for motorized traffic

Conflict Areas (CIE 115:200X)



Conflict areas occur whenever **vehicle streams intersect each other** or run into areas frequented by pedestrians, cyclists, or other road users, or when the existing road is connected to a stretch with **substandard geometry**, such as a reduced number of lanes or a reduced lane or road width.

For conflict areas, **luminance is the recommended design criterion**. However, where viewing distances are short and other factors prevent the use of the luminance criteria, **illumination** may be used on a part of the conflict area, or the entire area if the luminance criteria cannot be applied to the whole area.

M and C Lighting Classes of Comparable Lighting Level (CIE 115:200X)



Lighting class M		M1	M2	M3	M4	M5	M6
Average luminance L in cd/m²		2.0	1.5	1.0	0.75	0.50	0.30
Lighting class C	C0	C1	C2	C3	C4	C5	
Average illuminance E in lx	50	30	20	15	10	7.5	

For M classes valid for CIE road surface reflectance of CIE publication 144:2001, table C2 with $q_0=0.07$ cd/m²/lx

Selection of **C** Lighting Class (CIE 115:200X), Parameters for Conflict Areas



- Speed: high, moderate, or low
- Traffic volume: very high, high, moderate, low, or very low
- Traffic composition: motorized only, mixed, or mixed with high percentage of non-motorized
- Separation of carriageways: no or yes
- Ambient luminance: very high, high, moderate, low or very low
- Visual guidance, traffic control: poor, good, very good

Parameters for the Selection of a Lighting Class **C** for Conflict Areas (CIE 115:200X)



Parameter	Options	Weighting Value WV	WV selected
Speed	High	2	
	Moderate	1	
	Low	0	
Traffic volume	Very high	1	
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic composition	Mixed, high percentage of non-motorized	1	
	Mixed	0.5	
	Motorized only	0	
Separation of carriageways	No	1	
	Yes	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 Weighting Values	SWV

Parameters for the Selection of a Lighting Class C for Conflict Areas (example)



Parameter	Options	Weighting Value WV	WV selected
Speed	High	2	1
	Moderate	1	
	Low	0	
Traffic volume	Very high	1	0.5
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic composition	Mixed, high percentage of non-motorized	1	0.5
	Mixed	0.5	
	Motorized only	0	
Separation of carriageways	No	1	1
	Yes	0	
Ambient luminance	Very high	1	0.5
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very low	-1	
Visual guidance, traffic control	Poor	0.5	0.5
	Good	0	
	Very good	-0.5	
Number of Lighting Class C = 6 – SWV		Sum of Weighting Values	SWV = 4

C Lighting Classes (CIE 115:200X)



LIGHTING CLASS	Average illuminance over whole of used surface E in lx	Uniformity of illuminance U_o (E)	Threshold increment TI in % *	
			High and moderate speed	Low and very low speed
C0	50	0.40	10	15
C1	30	0.40	10	15
C2	20	0.40	10	20
C3	15	0.40	10	20
C4	10	0.40	15	25
C5	7.5	0.40	15	25

* Applicable where visual tasks usually considered for the lighting of roads for motorized traffic (M classes) are of importance

Lighting requirements for conflict areas

M and C Lighting Classes of Comparable Lighting Level (CIE 115:200X)



Lighting class M		M1	M2	M3	M4	M5	M6
Average luminance L in cd/m²		2.0	1.5	1.0	0.75	0.50	0.30
Lighting class C	C0	C1	C2	C3	C4	C5	
Average illuminance E in lx	50	30	20	15	10	7.5	

For M classes valid for CIE road surface reflectance of CIE publication 144:2001, table C2 with $q_0=0.07$ cd/m²/lx

M Lighting Classes (CIE 115:200X)



LIGHTING CLASS	dry			wet *	TI in %	SR
	L_{av} in cd/m^2	U_o	U_l	U_o		
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 where road surfaces are wet for a substantial part of the hours of darkness and appropriate road surface reflectance data are available

Lighting requirements for motorized traffic

Evaluation of Glare in Conflict Areas



CIE 115:1995, chapter 8 on the lighting of conflict areas:

„It is often **impractical** to use TI for the quantification of disability glare because the non-standard layouts used in conflict areas make its **calculation difficult**, and because the changing viewpoint of the driver makes the **adaptation luminance uncertain**. In these circumstances it is recommended that the glare is restricted by limiting the intensity to 30 cd/klm at 80° of elevation and to 10 cd/klm at 90°, at angles of azimuth at which the luminaires are viewed by the motorist.”

In view of adaptive road lighting systems this approach
is **not** adequate any longer.

Calculation of Threshold Increments



- Calculation of threshold increments requires knowledge of **veiling luminances** and **adaptation luminances** for particular observer positions and viewing directions
- Following the procedure for the **moving observer** as described in CIE 140:2000 there are **no restrictions** in terms of observer positions and viewing directions **in conflict areas**
- The **formula** for the calculation of **veiling luminances** **is valid** for any observer position and viewing direction – provided the limits are observed (see CIE 31:1796)
- According to CIE 31:1976 the **adaptation luminance may be approximated** (at fair luminance uniformities of the road surface) **by the average road surface luminance**

Approximation of Adaptation Luminance



- Adaptation luminance is approximated by average road surface luminance
- Average road surface luminance, calculated as arithmetic mean of the luminances obtained at the calculation points (CIE 140:2000), is assumed to correspond to the time average of the perspective average luminance seen when driving along a road (CIE 30:1796)
- In view of these conditions an additional realistic assumption concerning the average luminance of the conflict area will not add much to the overall uncertainty of the method

Average / Adaptation Luminance of Conflict Area



- Adaptation luminance **fixed** as average luminance of luminance class M of comparable lighting level to the selected illuminance class C for the conflict area (CIE 150:2003)

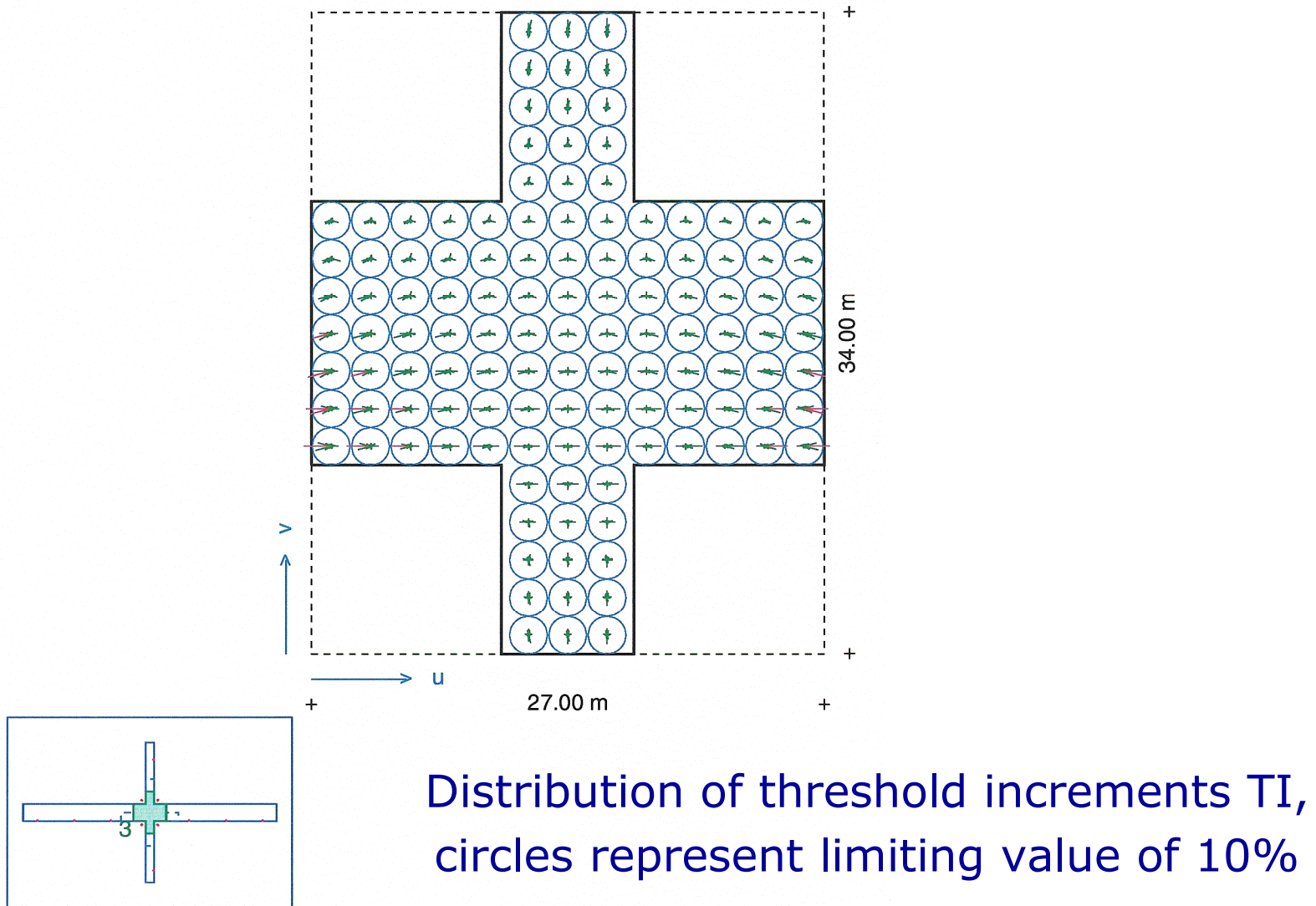
- Average luminance **calculated** from knowledge of average illuminance E and **average luminance coefficient q_0** using

$$L = q_0 \cdot E$$

- Average luminance **calculated** from knowledge of average illuminance E and **diffuse reflectance ρ** using

$$L = \rho / \pi \cdot E$$

Threshold Increments in Conflict Area



Selection of **P** Lighting Class (CIE 115:200X), Parameters for Pedestrian / Low Speed Areas



- Speed: low or very low (walking speed)
- Traffic volume: very high, high, moderate, low, or very low
- Traffic composition: pedestrians, cyclists and motorized traffic; pedestrians and motorized traffic; pedestrians and cyclists only; pedestrians only; cyclists only
- Parked vehicles: present or not present
- Ambient luminance: very high, high, moderate, low or very low
- Facial recognition: necessary or not necessary

Parameters for the Selection of a Lighting Class **P** for Pedestrian Areas (CIE 115:200X)



Parameter	Options	Weighting Value WV	WV selected
Speed	Low	1	
	Very low (walking speed)	0	
Traffic volume	Very high	1	
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic composition	Pedestrians, cyclists and motorized traffic	1	
	Pedestrians and motorized traffic	0.5	
	Pedestrians and cyclists only	0.5	
	Cyclists only	0	
	Pedestrians only	0	
Parked vehicles	Present	0.5	
	Not present	0	
Ambient luminance	Very high	1	
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very low	-1	
Facial recognition	Necessary	Additional requirements	
	Not necessary	No additional requirements	
		Sum of Weighting Values	SWV

Parameters for the Selection of a Lighting Class **P** for Low Speed Areas (**example**)



Parameter	Options	Weighting Value WV	WV selected
Speed	Low	1	0
	Very low (walking speed)	0	
Traffic volume	Very high	1	-0.5
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very Low	-1	
Traffic composition	Pedestrians, cyclists and motorized traffic	1	1
	Pedestrians and motorized traffic	0.5	
	Pedestrians and cyclists only	0.5	
	Cyclists only	0	
	Pedestrians only	0	
Parked vehicles	Present	0.5	0.5
	Not present	0	
Ambient luminance	Very high	1	0
	High	0.5	
	Moderate	0	
	Low	-0.5	
	Very low	-1	
Facial recognition	Necessary	Additional requirements	
	Not necessary	No additional requirements	
Number of Lighting Class P = 6 - SWF		Sum of Weighting Values	SWV = 1

Lighting Requirements for **P** Lighting Classes (Pedestrians/Low Speed Areas, CIE 115:200X)



LIGHTING CLASS	Average horizontal illuminance E_m in lx	Minimum horizontal illuminance E_{min} in lx	Threshold Increment TI in % *	Additional requirement if facial recognition is necessary	
				Minimum vertical illuminance $E_{v,min}$ in lx	Minimum semi-cylindrical illuminance $E_{sc,min}$ in lx
P1	15	3.0	20	5.0	3.0
P2	10	2.0	25	3.0	2.0
P3	7.5	1.5	25	2.5	1.5
P4	5.0	1.0	30	1.5	1.0
P5	3.0	0.6	30	1.0	0.6
P6	2.0	0.4	35	0.6	0.4

* Applicable where visual tasks usually considered for the lighting of roads for motorized traffic (M classes) and conflict areas (C classes) are of importance

To provide for uniformity the actual value of the maintained average illuminance may not exceed 1.5 times the value indicated for the class.

Parameters for the **Time dependent Selection** of Lighting Classes **P** for Pedestrian Areas



Parameter	Options	Weighting Values WV	WV selected			
			Δt_1	Δt_2	Δt_3	Δt_4
Speed	Low	1				
	Very low (walking speed)	0				
Traffic volume	Very high	1				
	High	0.5				
	Moderate	0				
	Low	-0.5				
	Very Low	-1				
Traffic composition	Pedestrians, cyclists and motorized traffic	1				
	Pedestrians and motorized traffic	0.5				
	Pedestrians and cyclists only	0.5				
	Cyclists only	0				
	Pedestrians only	0				
Parked vehicles	Present	0.5				
	Not present	0				
Ambient luminance	Very high	1				
	High	0.5				
	Moderate	0				
	Low	-0.5				
	Very low	-1				
Facial recognition	Necessary	Additional requirements				
	Not necessary	No additional requirements				
		Sum of Weighting Values SWV				

Time dependent Selection of Lighting Classes **P** for Pedestrian Area (example)



Parameter	Options	Weighting Values WV	WV selected			
			Δt_1	Δt_2	Δt_3	Δt_4
Speed	Low	1	1	0	0	0
	Very low (walking speed)	0				
Traffic volume	Very high	1	0.5	-0.5	0.5	-0.5
	High	0.5				
	Moderate	0				
	Low	-0.5				
	Very Low	-1				
Traffic composition	Pedestrians, cyclists and motorized traffic	1	1	0.5	0.5	0.5
	Pedestrians and motorized traffic	0.5				
	Pedestrians and cyclists only	0.5				
	Cyclists only	0				
	Pedestrians only	0				
Parked vehicles	Present	0.5	0	0.5	0.5	0.5
	Not present	0				
Ambient luminance	Very high	1	0.5	0.5	0.5	-0.5
	High	0.5				
	Moderate	0				
	Low	-0.5				
	Very low	-1				
Facial recognition	Necessary	Additional requirements				
	Not necessary	No additional requirements	x	x	x	x
Sum of Weighting Values SWV			3	1	2	1
Class P = 6 – SWV			P3	P5	P4	P5

Lighting Requirements for **P** Lighting Classes (Pedestrians/Low Speed Areas, CIE 115:200X)



LIGHTING CLASS	Average horizontal illuminance E_m in lx	Minimum horizontal illuminance E_{min} in lx	Threshold Increment TI in % *	Additional requirement if facial recognition is necessary	
				Minimum vertical illuminance $E_{v,min}$ in lx	Minimum semi-cylindrical illuminance $E_{sc,min}$ in lx
P1	15	3.0	20	5.0	3.0
P2	10	2.0	25	3.0	2.0
P3	7.5	1.5	25	2.5	1.5
P4	5.0	1.0	30	1.5	1.0
P5	3.0	0.6	30	1.0	0.6
P6	2.0	0.4	35	0.6	0.4

* Applicable where visual tasks usually considered for the lighting of roads for motorized traffic (M classes) and conflict areas (C classes) are of importance

To provide for uniformity the actual value of the maintained average illuminance may not exceed 1.5 times the value indicated for the class.

Luminous Intensity Classes (CIE 115:200X)



Class	Maximum luminous intensity in cd/klm			Other requirements
	at 70° and above ^{a)}	at 80° and above ^{a)}	at 90° and above ^{a)}	
G1		200	50	None
G2		150	30	None
G3		100	20	None
G4	500	100	10	Luminous intensities above 95° to be less than one cd/klm
G5	350	100	10	
G6	350	100	< 1	Luminous intensities above 90° to be less than one cd/klm

a) Any direction forming the specified angle from the downward vertical, with the luminaire installed for use.

For luminaires equipped with lamps of higher luminous fluxes it may be necessary to limit also the absolute intensities.



Conclusions

- New lamps, improved luminaires, and the introduction of electronic control gear have made it possible to introduce **adaptive lighting for roads** for motor and pedestrian traffic
- The **new model** for the selection of appropriate lighting classes (M for motorized traffic, C for conflict areas, or P for pedestrian and low speed areas) takes into account the different parameters relevant for the given visual tasks
- Applying **time dependent variables** like traffic volume or traffic composition the model offers the possibility to use adaptive lighting systems in many circumstances
- Adaptive road lighting systems offer **potential energy savings**, and i.e. CO₂ reductions, while **keeping safety and comfort at an appropriate level**



„Adaptive Road Lighting“
according to CIE Publication 115:200X
**„Lighting of Roads for Motor
and Pedestrian Traffic“**

End

Thank you very much for your attention!