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Public Lighting Standards - Part II (applications)

Prof. Axel Stockmar, LiTG e.V., Hannover University of Applied Sciences and Arts

Main and Specific Objectives of the Interreg Project Dynamic Light (CE 452)

- The **main objective** of this project is to make a shift from conventional municipal infrastructure planning towards a modern **energy efficient and demand-orientated lighting** design and better light and energy management.

- The process itself presents smart solutions that will be developed and implemented as **test pilots within the project lifetime**.

- They will significantly contribute to the reduction of CO_2-emissions in local districts and regions and enhance the quality of stay.

- The **specific objectives** comprise the promotion of user-accepted energy efficient lighting solutions by improving the quality of light according to social needs and to **harmonize public lighting standards and norms**.

Working Definition of Dynamic / Adaptive Lighting

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- (Urban) **dynamic lighting is adaptive lighting**, i.e. it is being provided **where and when it is needed** depending on different variable conditions, such as **travelling speed, traffic volume and/or composition, ambient luminances, weathers and other exterior factors** in a way that **it reduces light pollution as well as energy consumption**; beyond that **it recognizes varying human and social needs**, such as aesthetics or feeling of safety, as a basic concern and key factor in the design of adaptive public lighting

- TR 13201-1:2014 'Road lighting - Part 1: Guidelines on selection of lighting classes'
- **EN 13201-2:2015 'Road lighting - Part 2: Performance requirements'**
- EN 13201-3:2015 'Road lighting - Part 3: Calculation of performance'
- EN 13201-4:2015 'Road lighting - Part 4: Methods of measuring lighting performance'
- EN 13201-5:2015 'Road lighting - Part 5: Energy performance indicators'
- EN 13032-5:2018 'Light and lighting - Measurement and presentation of photometric data of lamps and luminaires - Part 5: Presentation of data for luminaires used for road lighting'

Lighting Classes M for Motorized Traffic

Lighting class	Road surface luminance				Threshold increment	Lighting of the surroundings
	Dry			Wet		
	L_{av} in cd/m²	U_o	U_l	U_{ow}	f_{TI} in %	R_{EI}
M1	2.00	0.40	0.70	0.15	10	0.35
M2	1.50	0.40	0.70		10	0.35
M3	1.00	0.40	0.60		15	0.30
M4	0.75	0.40	0.60		15	0.30
M5	0.50	0.35	0.40		15	0.30
M6	0.30	0.35	0.40		20	0.30

L_{av} average luminance
U_o overall uniformity
U_l longitudinal uniformity
U_{ow} overall uniformity, wet
F_{TI} threshold increment
R_{EI} edge illuminance ratio

Lighting Classes C for Conflict Areas

Lighting class	Average illuminance over whole of used surface E_{av} in lx	Uniformity of illuminance U_o (E)	Threshold increment f_{TI} in %
C0	50	0.40	15
C1	30	0.40	15
C2	20	0.40	15
C3	15.0	0.40	20
C4	10.0	0.40	20
C5	7.50	0.40	20

Lighting Classes P for Pedestrian Areas

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Lighting Class	Average horizontal illuminance $E_{h,av}$ in lx [a]	Minimum horizontal illuminance $E_{h,min}$ in lx	Threshold increment f_{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	15.0	3.00	20	5.0	3.0
P2	10.0	2.00	25	3.0	2.0
P3	7.50	1.50	25	2.5	1.5
P4	5.00	1.00	30	1.5	1.0
P5	3.00	0.60	30	1.0	0.6
P6	2.00	0.40	35	0.6	0.4
P7	---	---	---	---	---

[a] To provide for uniformity, the actual value of the maintained average illuminance shall not exceed 1,5 times the average value indicated for the class.

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Selection of an Appropriate Lighting Class, Parameters to be Considered

- For the selection of an appropriate lighting class as well as for the application of adaptive lighting a number of various parameters are considered in the different technical reports or standards.
- These parameters are generally related to:
  - **the geometry of the area under consideration (fixed)**
  - **the traffic use of the area (time-dependent)**
  - **the influence of the surrounding environment (time-dependent)**
- The most comprehensive number of parameters to be taken into account, covering the lighting classes M for motorized traffic, C for conflict areas, and P for pedestrian and low speed areas, can be found in the technical report CEN/TR 13201-1:2014.
- In the different standards usually only a sub-set of these parameters is considered, in some cases with different names for the same influence.

Lighting Classes M for Motorized Traffic

- 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, and the limitation of disability glare.
- The **most important** (fixed or time-dependent) **parameters** to be considered are:
  - Speed
  - Traffic volume
  - Traffic composition
  - Separation of carriageways
  - Intersection density
  - Parked vehicles
  - Ambient luminance
  - Difficulty of navigational task / Visual guidance / Traffic control

Selection of a Lighting Class M, (CEN/TR 13201-1:2014)

Parameter	Options	Description [a]		Weighting Value V_W [a]
Design speed or speed limit	Very high	v ≥ 100 km/h		2
	High	70 < v < 100 km/h		1
	Moderate	40 < v ≤ 70 km/h		-1
	Low	v ≤ 40 km/h		-2
Traffic volume		Motorways, multilane routes	Two lane routes	
	High	> 65 % of maximum capacity	> 45 % of maximum capacity	1
	Moderate	35 % - 65 % of maximum capacity	15 % - 45 % of maximum capacity	0
	Low	< 35 % of maximum capacity	< 15 % of maximum capacity	-1
Traffic composition	Mixed with high percentage of non-motorised			2
	Mixed			1
	Motorised only			0
Separation of carriageway	No			1
	Yes			0
Junction density		Intersection/km	Interchanges, distance between bridges, km	
	High	> 3	< 3	1
	Moderate	≤ 3	≥ 3	0
Parked vehicles	Present			1
	Not present			0
Ambient luminosity	High	shopping windows, advertisement expressions, sport fields, station areas, storage areas		1
	Moderate	normal situation		0
	Low			-1
Navigational task	Very difficult			2
	Difficult			1
	Easy			0

[a] The values stated in the column are an example. Any adaptation of the method or more appropriate weighting values can be used instead, on the national level.

Lighting Classes C for Conflict Areas

- Conflict areas occur wherever **vehicle streams intersect each other** or run into areas frequented by pedestrians, cyclists, or other road users.
- Areas showing a **change in road geometry**, such as a reduced number of lanes or a reduced lane or carriageway width (an area with measures of traffic calming), are also regarded as conflict areas.
- Their existence results in an **increased potential for collisions** between vehicles, between vehicles and pedestrians, cyclists and other road users, and/or between vehicles and fixed objects.
- The **lighting of a conflict area** should reveal the position of the kerbs and the road markings, the directions of the roads, the presence of pedestrians, other road users, and/or obstructions, and the movement of vehicles in the vicinity.

Selection of a Lighting Class C, (CEN/TR 13201-1:2014)

Parameter	Options	Description [a]	Weighting Value V_W [a]
Design speed or speed limit	Very high	v ≥ 100 km/h	3
	High	70 < v < 100 km/h	2
	Moderate	40 < v ≤ 70 km/h	0
	Low	v ≤ 40 km/h	-1
Traffic volume	High		1
	Moderate		0
	Low		-1
Traffic composition	Mixed with high percentage of non-motorized		2
	Mixed		1
	Motorized only		0
Separation of carriageway	No		1
	Yes		0
Parked vehicles	Present		1
	Not present		0
Ambient luminosity	High	shopping windows, advertisement expressions, sport fields, station areas, storage areas	1
	Moderate	normal situation	0
	Low		-1
Navigational task	Very difficult		2
	Difficult		1
	Easy		0

[a] The values stated in the column are an example. Any adaptation of the method or more appropriate weighting values can be used instead, on the national level.

Lighting Classes P for Pedestrian Areas

- The lighting classes P are intended predominantly for **pedestrians and pedal cyclists** for use on footways and cycle ways, but also for drivers of **motorized vehicles at low speed** in pedestrian areas, on emergency or parking lanes, and for other road areas lying separately or along a carriageway of a traffic route or a residential road etc.
- The **visual tasks, sometimes vertical**, i.e. recognition of faces, and needs of pedestrians differ from those of drivers in many respects.
- **Speed of movement is generally much lower** and relevant objects to be seen are closer than those important for drivers of motorized vehicles.

Selection of a Lighting Class P, (CEN/TR 13201-1:2014)

Parameter	Options	Description [a]	Weighting Value V_W [a]
Travel speed	Low	v ≤ 40 km/h	1
	Very low (walking speed)	Very low, walking speed v ≤ 5 km/h	0
Use intensity	Busy		1
	Normal		0
	Quiet		-1
Traffic composition	Pedestrians, cyclists and motorized traffic		2
	Pedestrians and motorized traffic		1
	Pedestrians and cyclists only		1
	Pedestrians only		0
	Cyclists only		0
Parked vehicles	Present		1
	Not present		0
Ambient luminosity	High	shopping windows, advertisement expressions, sport fields, station areas, storage areas	1
	Moderate	normal situation	0
	Low		-1
Facial recognition	Necessary		Additional requirements [b]
	Not necessary		No additional requirements

[a] The values stated in the column are an example. Any adaptation of the method or more appropriate weighting values can be used instead, on the national level. [b] Specific guidelines on use of facial recognition parameters are defined at national level for each country.

Selection of Appropriate Lighting Class M, C or P

For the determination of the number of the appropriate lighting class to be applied the weighting values for the different parameters have to be added (if necessary for each adaptive lighting time interval considered), leading to the **sum of weighting values V_{ws}.**

Number of lighting class M = 6 - V_{ws}

Number of lighting class C = 6 - V_{ws}

Number of lighting class P = 6 - V_{ws}

Careful selection of appropriate weighting values will yield class numbers between 1 and 6 (lighting classes M and P) or between 0 and 5 (lighting classes C). If the sum of the weighting values is < 0 the value 0 shall be applied (lighting classes M and P), or if the sum of the weighting values is ≤ 0 the value 1 shall be applied (lighting class C).

Alternative Method for Selection of a Lighting Class, (CEN/TR 13201-1:2014, Annex B, Table B1)

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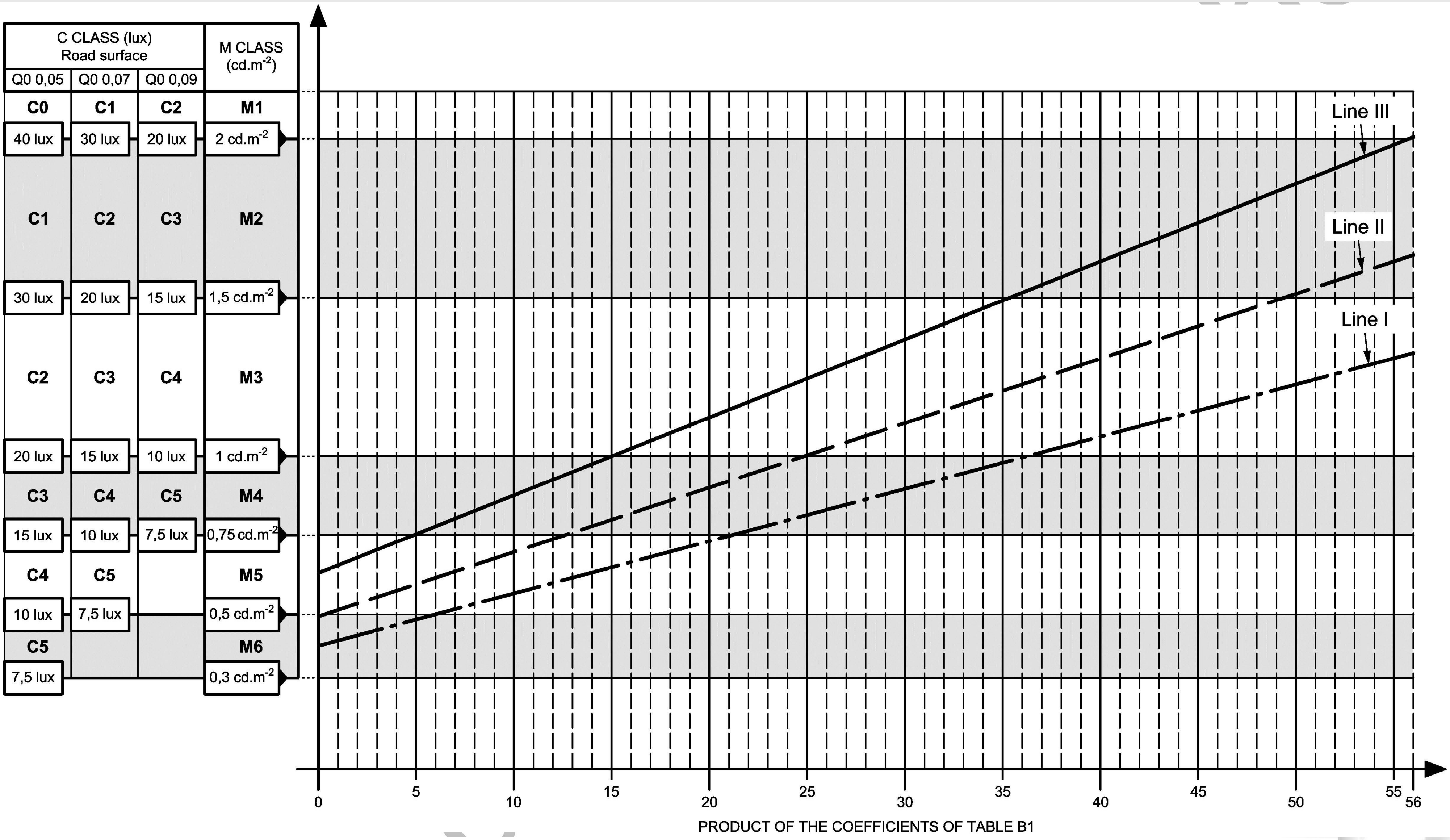
Roads or streets designation	CARRIAGEWAY & SPEED LIMIT				TRAFFIC									A	B	C	Overall coefficient	
	Carriageway		Speed	Coefficients carriageway speed	Composition				Volume			Ambient luminosity	Mental task load	Product speed traffic	Ambient luminosity	Mental task load	A x B or A x C	A x B x C
					Coefficients				Coefficients			Coefficients			Coefficients			
					1	2	3	4	3	2	1	1	1		1,25	1,25		
	single	separated	km/h		Not motorized	Motorized only	Mixed traffic	Mixed mainly not motorized	High	Medium	Low	Low to moderate		Line I *	High	High	Line II *	Line III *
Interurban motorway		X	≤ 130	5		2			3			●	●	30	—	●	38	
										2				20			25	
											1			10			12	
Urban motorway Expressway		X	≤ 110	5		2			3			—	—		●	●	38	47
										2							25	31
											1						12	16
Interurban main road	X		≤ 90	5			3		3			●	●	45	—	●	56	
										2				30			38	
											1			15			19	
Main crossing road	X		≤ 70	4			3		3			—	—		●	●	45	56
										2							30	37
											1						15	19
Main urban road Boulevard - Avenue	X		≤ 50	3			3		3			—	—		●	●	34	42
										2							23	28
											1						11	14
Secondary urban road Avenue - Street	X		≤ 50	3			3					●	●		●	—		
										2				18			22	
											1			9			11	
Urban service road	X		≤ 50	2			3					●	●		●	—		
										2				12			15	
											1			6			8	
Urban road Dangerous intersections Village crossing	X		≤ 50	3			3		3			●	●	27	●	●	34	42
										2				18			23	28
											1			9			11	14
Urban road in dangerous section	X		≤ 30	1				4	3			●	●	12	●	●	15	18
										2				8			10	12
											1			4			5	7

* see Figure B1

— Unlikely case

● Current possible case

Selection of lighting Class M or C versus the Overall Coefficient, (CEN/TR 13201-1:2014, Annex B)



Alternative Method for Selection of a Lighting Class, (CEN/TR 13201-1:2014, Annex B, Table B2)

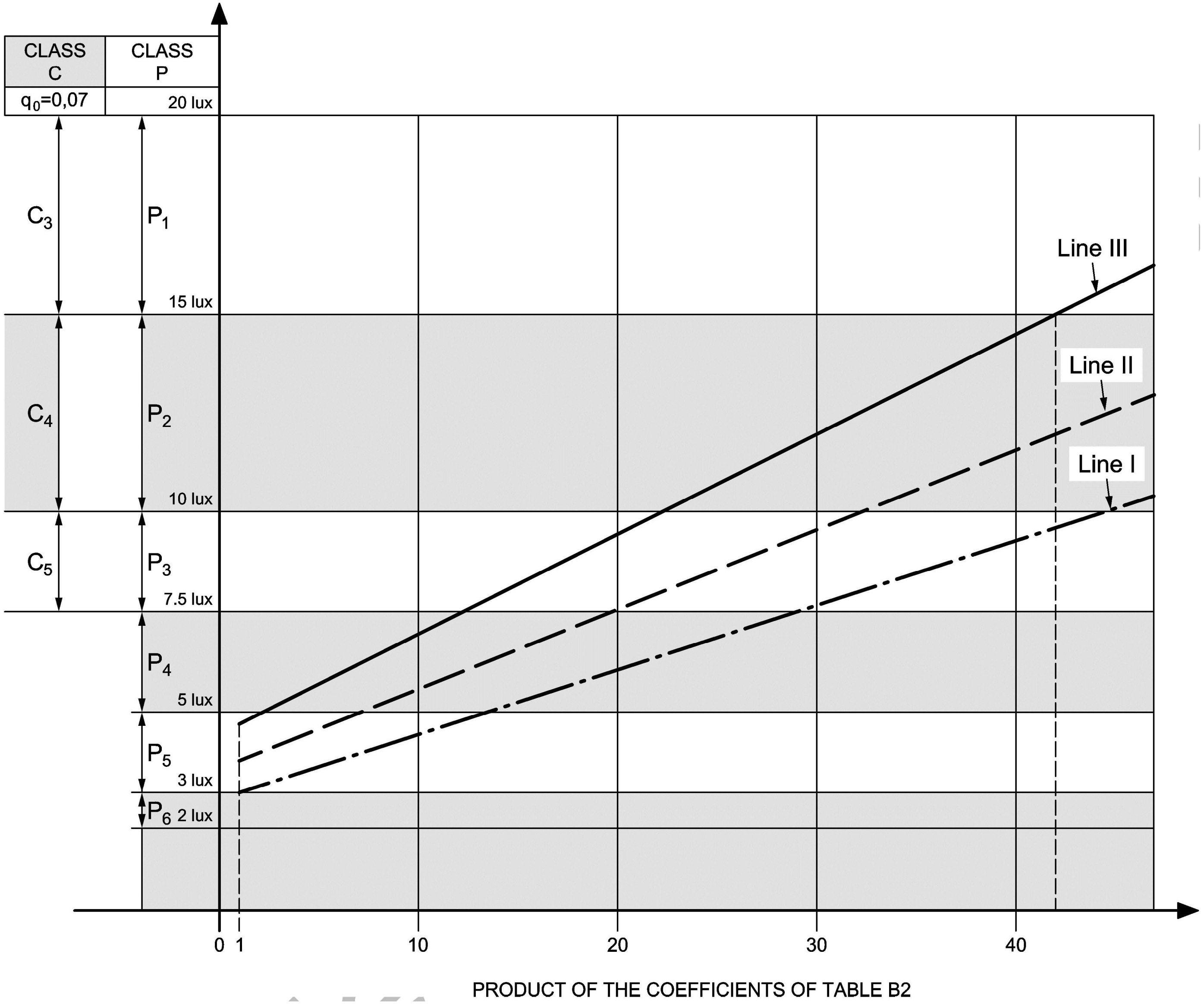
P Class	SPEED LIMIT		TRAFFIC						Ambient luminosity	Mental task load Face recognition	A	B	C	Overall coefficient	
			Composition			Volume					Product Speed x Traffic composition volume	Ambient luminosity	Mental task load - Face Recognition	A x B or A x C	A x B x C
Road designation	km/h	Coefficient	Mixed	Pedestrians and Cycles	Pedestrians or Cycles	High	Medium	Low	Low to moderate			High			
			coefficients									coefficients			
			3	2	1	3	2	1	1	1	Line I *	1,25	1,25	Line II *	Line III *
Low speed Roads with traffic priority - Mopeds Cycles and Pedestrians	S < 40	3	3			3			—	—		●	●	34	42
							2							23	28
								1						12	14
Roads without motorized traffic		2		2		3			●	●	12	●	●	15	19
							2				8			10	13
								1			4			5	7
Walkway	Pedestrian speed	1			1	3			●	●	3	●	●	4	5
							2				2			3	4
								1			1			2	3
Bicycle path	Bikes only	2			1	3			●	●	6	●	●	8	10
							2				4			5	7
								1			2			3	4

* see Figure B2

— Unlikely case

● Current possible case

Selection of lighting Class P versus the Overall Coefficient, (CEN/TR 13201-1:2014, Annex B)



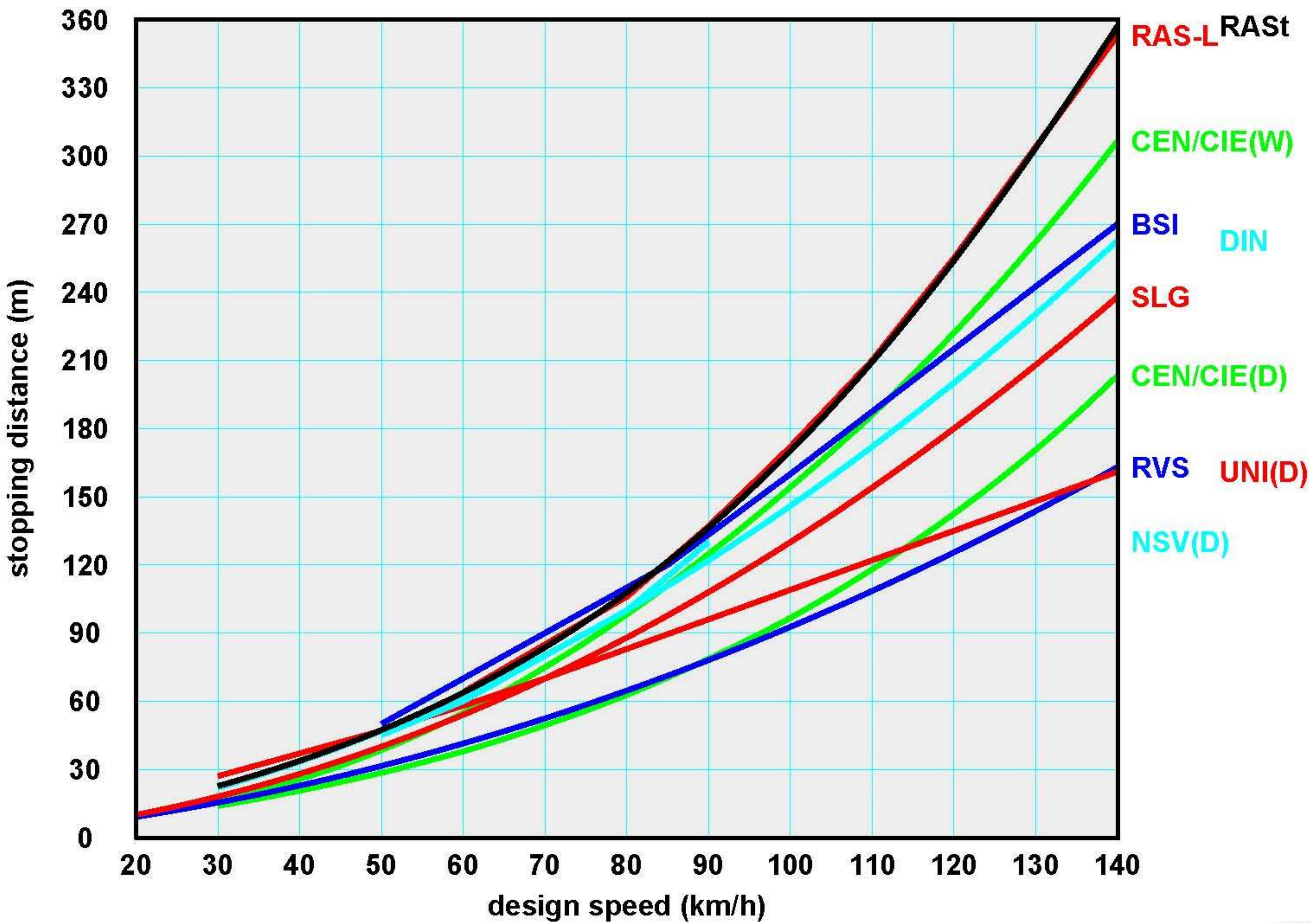
Lighting Classes M, C, P of Comparable Lighting (Luminance) Level

Lighting Class M			M1	M2	M3	M4	M5	M6			
Rated average luminance in cd/m^2	5.00	3.00	2.00	1.50	1.00	0.75	0.50	0.30	0.20	0.15	0.10
Lighting Class C for q_0 = 0.05 1/sr			C0	C1	C2	C3	C4	C5			
Lighting Class C for q_0 = 0.07 1/sr		C0	C1	C2	C3	C4	C5				
Lighting Class C for q_0 = 0.09 1/sr	C0	C1	C2	C3	C4	C5					
Lighting Class C or P for ρ = 0.15			C0	C1	C2	P1	P2	P3	P4	P5	P6
Lighting Class C or P for ρ = 0.20		C0	C1	C2	P1	P2	P3	P4	P5	P6	
Lighting Class C or P for ρ = 0.30	C0	C1	C2	P1	P2	P3	P4	P5	P6		

Adaptive / Dynamic Lighting, Parameter Speed

- From the road safety point of view the relationship between speed and stopping distance is one of the most important aspects.
- The **stopping distance** is the sum of two stretches, i.e. the distance covered during the **reaction time** and the distance covered during the **breaking time**.
- For known friction coefficients the stopping distance is a function of speed, and can be calculated for a given slope of the road assuming a certain reaction time.
- In recommendations and regulations **across Europe** the specified reaction time varies between 1 s and 2 s, and friction coefficients for dry and wet conditions are not harmonized at all.
- For the relevant speeds between 30 km/h and 100 km/h the resulting **absolute stopping distances differ by a factor of almost two**, but in all cases the decrease of the stopping distance as a function of speed is significant.
- As an example, the stopping distance for a speed of 30 km/h (option ‘low’) is on average **shorter by a factor of two** compared to the stopping distance for a speed of 50 km/h (option ‘moderate’).

Stopping distance as function of speed according to different national and international regulations



Adaptive / Dynamic Lighting, Traffic Volume Related Examples

- On a **radial road**, usually a dual carriageway, the traffic volume during peak hours in the morning and in the evening could be very different for the carriageways serving the two directions.
- On a **commercial street** there could be almost no traffic during the weekends.
- A **shopping street** may carry more traffic during the late afternoon hours of darkness compared to the early morning hours of darkness.
- A **residential or local street** leading to a school complex is busier during the hours of darkness in the morning than in the afternoon.
- **Roads providing access to sports** and/or leisure **facilities** are used more frequently during the hours of darkness in the afternoon or evening than in the morning.
- **Roads servicing exhibition areas or big stadia** may be used only some days during a year.

Ref.: 'Intelligent Energy - Europe' (IEE) project 'Energy Saving Outdoor Lighting' (ESOLi), 2012

Adaptive / Dynamic Lighting, Parameter Traffic Composition (I)

- The parameter ‘**traffic composition**’ has been introduced to consider the influence of different users of a certain traffic area on the resulting risk caused e.g. by differences in the speed of movement and/or changes of the visual conditions.

- For lighting classes M and C, predominantly intended for motorized traffic, the influence of the amount of non-motorized users is taken into account by the options ‘mixed’ and ‘mixed with high percentage of non-motorized’.

- If during certain hours of darkness, e.g. **between 11 p.m. and 5 a.m.**, the number of non-motorized users is (assumed or known to be) low, the option for the parameter traffic composition could be changed from ‘mixed with high percentage of non-motorized’ to ‘mixed’ (for lighting classes M and C).

Adaptive / Dynamic Lighting, Parameter Traffic Composition (II)

- For lighting classes P, predominantly intended of pedestrian and low speed traffic, the parameter ‘**traffic composition**’ allows to take into account the different users, pedestrians, cyclists, and motorized vehicles, (separate or together) of a traffic area at a certain moment.
- In pedestrian and low speed areas (lighting classes P) the access for motorized vehicles and/or cycles is quite often restricted to certain hours of a day and/or to certain days of a week.
- If these time frames coincide with some hours of darkness the option for the parameter traffic composition may be reconsidered and adjusted (e.g. no motorized vehicles, no cyclists).
- In all these cases the **temporal change of the traffic composition** could result in reduced lighting requirements, i.e. adaptive / dynamic lighting could be applied to provide the appropriate lighting levels.

Adaptive / Dynamic Lighting, Parameter Separation of Carriageways

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- The separation of carriageways (considered only for lighting classes M and C) is regarded as an effective safety measure, in particular in form of a **central reserve of not less then three metres** in width with guardrails for ‘high’ and ‘very high’ speed roads.
- If, from **long term observations of the traffic volume profiles**, it is known that during certain hours of darkness one of the carriageways is carrying considerably less traffic than the other, adaptive / dynamic lighting could be used to provide different adequate lighting levels for the two carriageways.
- If only one carriageway is used temporarily, e.g. during road works, the higher risk without separation could be counterbalanced with a speed reduction. An appropriate choice of the options for the parameters ‘speed’ and ‘separation of carriageways’ will result in an unchanged weighting value, i.e. in unaltered lighting requirements.

Adaptive / Dynamic Lighting, Parameter Junction Density (I)

- The ‘**intersection density**’ (for lighting classes M only) is considered as ‘high’ if there are more than three intersections per kilometre, else it is rated as ‘moderate’.

- The intersection is defined as the general area where two or more roads join at the same level.

- The limit of three intersections per kilometre is in line with general assumptions concerning the **application of the luminance concept**; i.e. a more or less **straight section of the road of a length not less than 20 to 22 times the mounting height** and the evaluation of disability glare taking into account all luminaires up to a distance of 500 m in front of the road user.

Adaptive / Dynamic Lighting, Parameter Junction Density (II)

- In a similar way the '**intersection density**' is considered as 'moderate' for interchange spacings - or distances between bridges respectively - greater than or equal three kilometres, else it is rated as 'high'.
- The interchange is defined as a grade separated junction with one or more turning roadways (ramps) for travel between the through roads.
- The intersection density is an intrinsic property of the overall road layout. Under these circumstances the application of adaptive / dynamic lighting is not adequate unless it is foreseen that in the not too distant future the number of intersections will be increased considerably, and at the same time leading to an increased traffic volume. In such cases adaptive / dynamic lighting could be used at an appropriately reduced lighting level until the road is in full operation.

Adaptive / Dynamic Lighting, Parameter Parked Vehicles (I)

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- **Parked vehicles** are regarded as obstacles on the road, increasing the general risk and causing some obstruction to the driver's view. Therefore the parameter 'parked vehicles' with the options 'present' and 'not present' is considered to be important for all lighting classes (M, C, and P).
- In **the simplified approach using only whole numbers for the weighting values** it is not possible to take into account the speed dependence of the risk.
- The presence of parked vehicles could be restricted to certain hours of a day or to certain days of a week, e.g. on single or dual carriageways (lighting classes M and C) parked vehicles on the carriageway may not be allowed during rush hours, in pedestrian areas (lighting classes P) motorized traffic is restricted generally.

Adaptive / Dynamic Lighting, Parameter Parked Vehicles (II)

- If the hours of darkness coincide to some extend with the hours of restricted parking, the option for the parameter parked vehicles could be changed from ‘present’ to ‘not present’, resulting in reduced lighting requirements.
- At the same time, e.g. during rush hours on a single or dual carriageway, an increased traffic volume could be expected, possibly demanding a higher lighting level.
- Depending on specific circumstances adaptive / dynamic lighting could be applied, but decisions have to be taken with great care.
- Is the outer parking lane as part of the carriageway to be considered as a conflict area (lighting classes C, illuminance requirements), or are lighting classes M for motorized traffic applicable, although these classes are linked to the luminance concept, i.e. to the average luminance of the road surface which cannot be seen by the road users due to the parked vehicles?

Adaptive / Dynamic Lighting, Parameter Ambient Luminance (I)

- The luminance (brightness) distribution in the visual field controls the adaptation level of the eyes. The higher the adaptation level of the visual system, the more sensitive it is to low contrasts, and less sensitive it is to glare.
- The **adaptation luminance** is usually approximated by the average road surface luminance in front of the road user created by the road lighting installation.
- If parts of the surroundings, e.g. shop windows, displays, advertisement signs, are so bright that a significant increase of the veiling luminance is to be expected, a higher adaptation luminance, approximated by the average road surface luminance, has to be provided to keep the visual conditions, here expressed in terms of the threshold increment TI, at the required level.

Adaptive / Dynamic Lighting, Parameter Ambient Luminance (II)

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- Depending on the original lighting level and on the expected (or calculated for critical situations foreseen) change of the **ratio of veiling luminance to adaptation luminance** the option for the parameter ambient luminance has to be changed appropriately to ‘moderate’, or even ‘high’. This could lead to an increase of the required lighting level by a factor of two.
- In extreme cases, e.g. using **video walls** with average luminances of several hundred cd/m^2, it is not realistic to counterbalance the possible glare by increasing the lighting level; dimming of such ‘glare’ sources during the hours of darkness would be the obvious choice.
- Some of the **glare sources will be regarded as obtrusive light** which is defined as light giving rise to annoyance, discomfort, distraction or a reduction in the ability to see essential information. For the control of obtrusive lighting in general stricter requirements apply during certain periods of the night (curfew), usually fixed by local authorities.

Adaptive / Dynamic Lighting, Parameter Navigational Task / Traffic Control (I)

- The execution of guidance manoeuvres is assisted by traffic safety devices, like road surface markings, delineators, and/or traffic signs or lights.
- The parameter '**difficulty of navigational task**', defined as the degree of effort necessary by the road user, as a result of the information presented, to select route and lane, and to maintain or change speed and position on the carriageway, is used to take account of the existence of such devices and/or of the difficulty to recognize them at adverse weather conditions.
- Traffic signs or traffic lights, here considered as parameter 'traffic control', could help to reduce the overall risk.
- The option to be selected (between 'very difficult', 'difficult', and 'easy') for the given situation could have a significant influence on the lighting requirements.

Adaptive / Dynamic Lighting, Parameter Navigational Task / Traffic Control (II)

- If the lighting installation has been designed to fulfil the requirements for ‘very difficult’ conditions, e.g. for adverse (winter) weather conditions, adaptive / dynamic lighting could be applied to reduce the lighting level during periods of ‘easy’ conditions, e.g. during the dry summer.
- The decision to change the lighting level for a longer period of time should be based principally on long term observation/experience.
- The **provision of traffic lights**, in particular in conflict areas, could allow to change the option from ‘difficult’ to ‘easy’ and to adjust the lighting requirements accordingly.
- However, if the surroundings are intrinsically dark, and the option for the parameter ‘ambient luminance’ is selected as ‘low’, **traffic lights could become a glare source**, thus requiring a higher lighting level.

Adaptive / Dynamic Lighting, Parameter Facial Recognition

- The parameter '**facial recognition**' is considered only for lighting classes P, intended predominantly for pedestrians.
- The recognition of another pedestrian's face at a certain distance requires some vertical lighting at a height of about 1.5 m above the ground.
- The level of the **vertical illuminance** should be about one third, the level of the **semi-cylindrical illuminance** about one fifth of the horizontal illuminance
- If this is accomplished with increased lighting or even better with additional lighting using more appropriate intensity distributions or **multi-variable distributions**, adaptive / dynamic lighting could be applied to adjust the lighting during certain hours of darkness dependent on the expected or actual traffic flow of pedestrians.

Adaptive / Dynamic Lighting, Other Possible Parameters

- For moderate and low speed traffic areas (lighting classes M and C) special attention is sometimes given to the (geometry related) parameter ‘**measures for traffic calming**’.
- Generally, only in the area of traffic calming the higher lighting requirements of the lighting class numbered one step lower have to be fulfilled. This is equivalent to the consideration of an area of traffic calming as a conflict area.
- For traffic areas for motorized traffic (lighting classes M) the ‘**main weather type**’ is sometimes considered as a special parameter.
- The overall uniformity for wet conditions is the only additional requirement to be applied if the road surfaces are rated ‘wet’ for an expected substantial part of the hours of darkness and appropriate road surface data are available.
- Therefore the ‘main weather type’ has not to be regarded as a special parameter as long as the associated lighting requirements are applied.

Handbook about Interpretation of EN 13201, Contents (part I)

Handbook about Interpretation of EN 13201, Contents (part II)

Power Density Indicator (PDI), EN 13201-5:2015

$$D_P = \frac{P}{\sum_{i=1}^{n} E_i \cdot A_i}$$

D_P	power density indicator in W/(lx·m^2) or in W/lm
P	system power of the lighting installation used to light the relevant areas in W
E_i	maintained average horizontal illuminance of the sub-area i in lx
A_i	size of sub-area i lit by the lighting installation in m^2
n	number of sub-areas to be lit

Annual Energy Consumption Indicator (AECI), EN 13201-5:2015

$$D_E = \frac{\sum_{j=1}^{m} P_j \cdot t_j}{A}$$

D_E	annual energy consumption indicator for a road lighting installation in Wh/m^2
P_j	operational power associated with the j^{th} period of operation in W
t_j	duration of j^{th} period of operation profile when power P_j is consumed in h
A	size of the area lit by the same arrangement in m^2
m	number of periods with different operational power P_j

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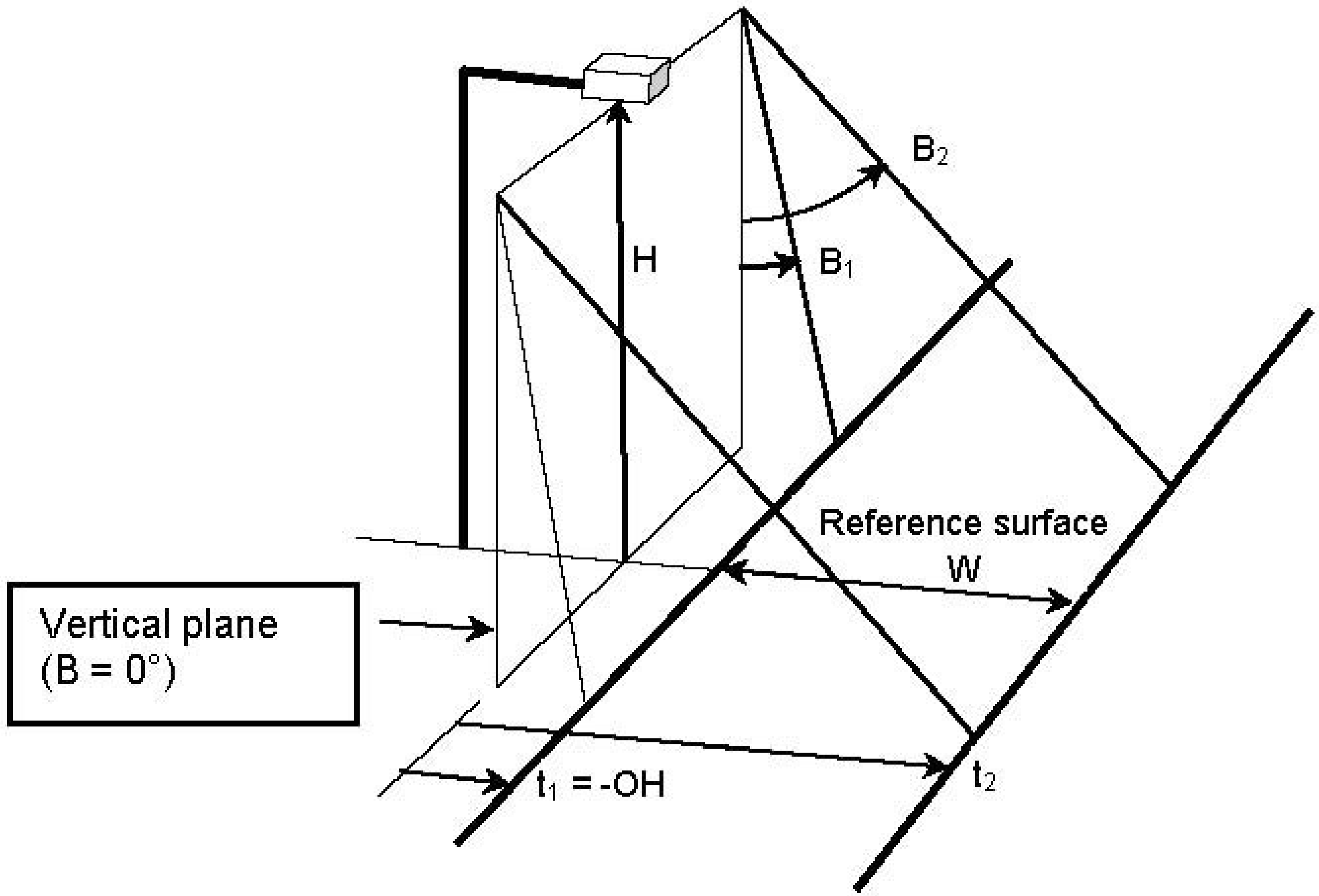
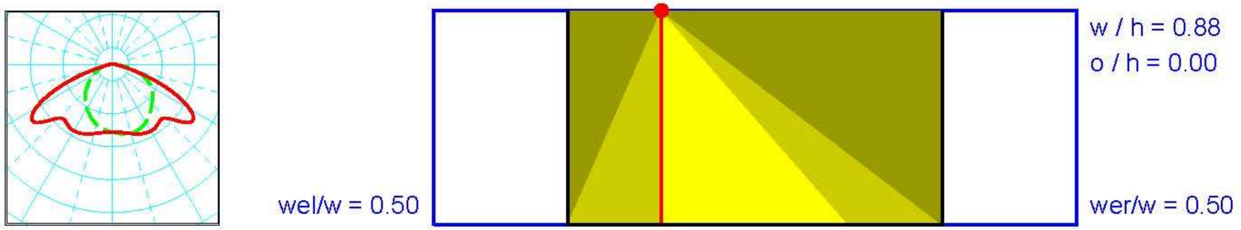
- The energy efficiency of a road lighting installation depends strongly on the utilization factor road lighting
- The **utilization factor road lighting** is defined as the ratio of the luminous flux received by one or more parallel strips along the road to the sum of the individual total fluxes of the lamps / light sources of the installation
- But in this European standard utilance is used in place of utilization factor because it can be applied to **luminaires with replaceable or non-replaceable lamps / light sources**
- The **utilance road lighting** is defined as the ratio of the luminous flux received by one or more parallel strips along the road to the sum of the individual total fluxes of the luminaires of the installation

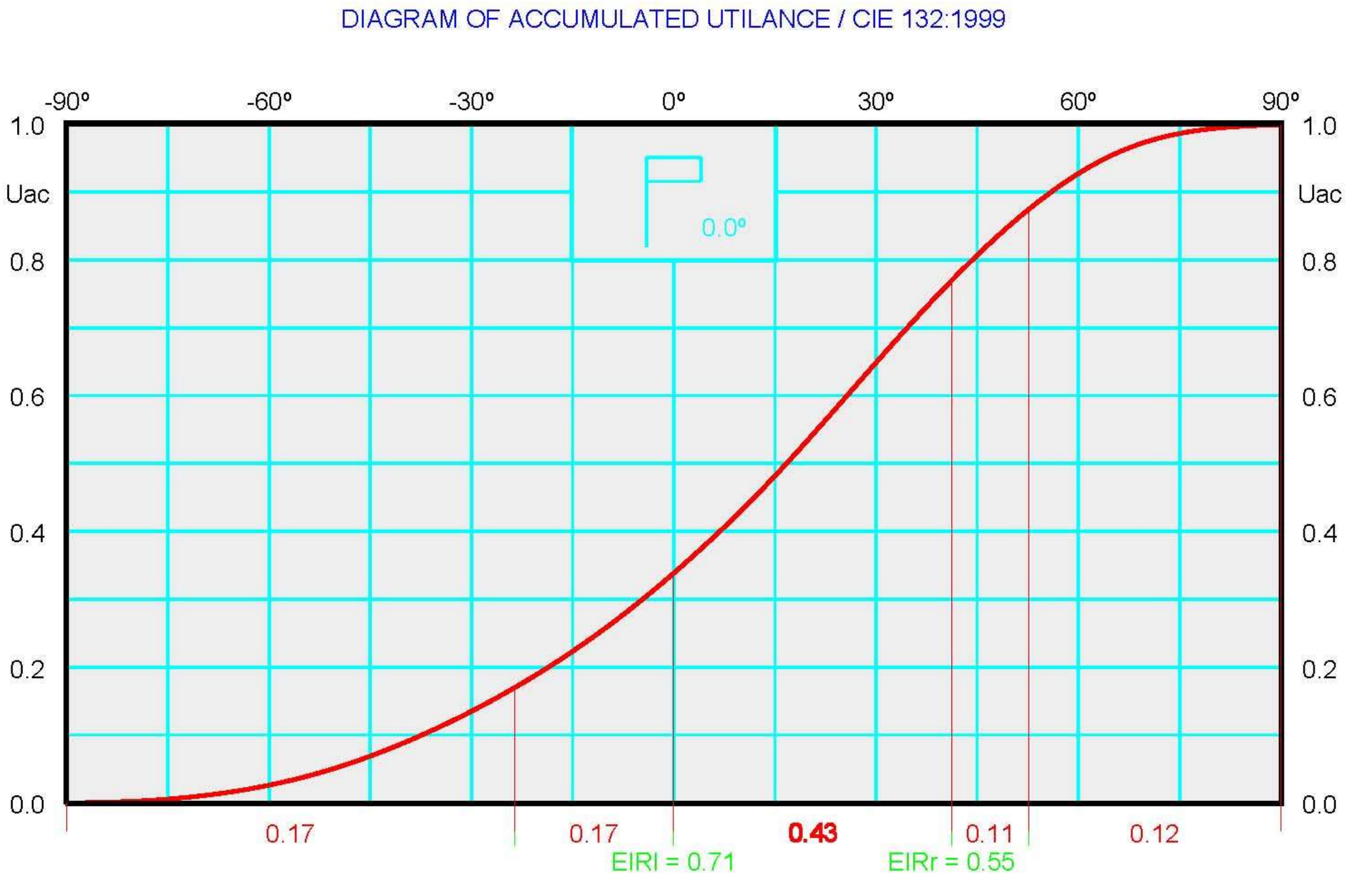
Basic Position of Reference Area relative to a Luminaire in a Row of Luminaires, EN 13032-5:2018



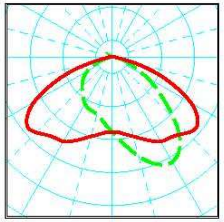
O_V overhang (m); W width of reference area (m); H luminaire mounting height (m); t_1, t_2 transverse distances to limiting lines; B_1, B_2 angles of inclined limiting planes (°)

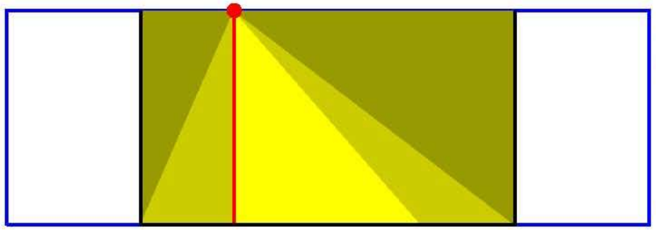
Accumulated Utilances, (conventional luminaire)

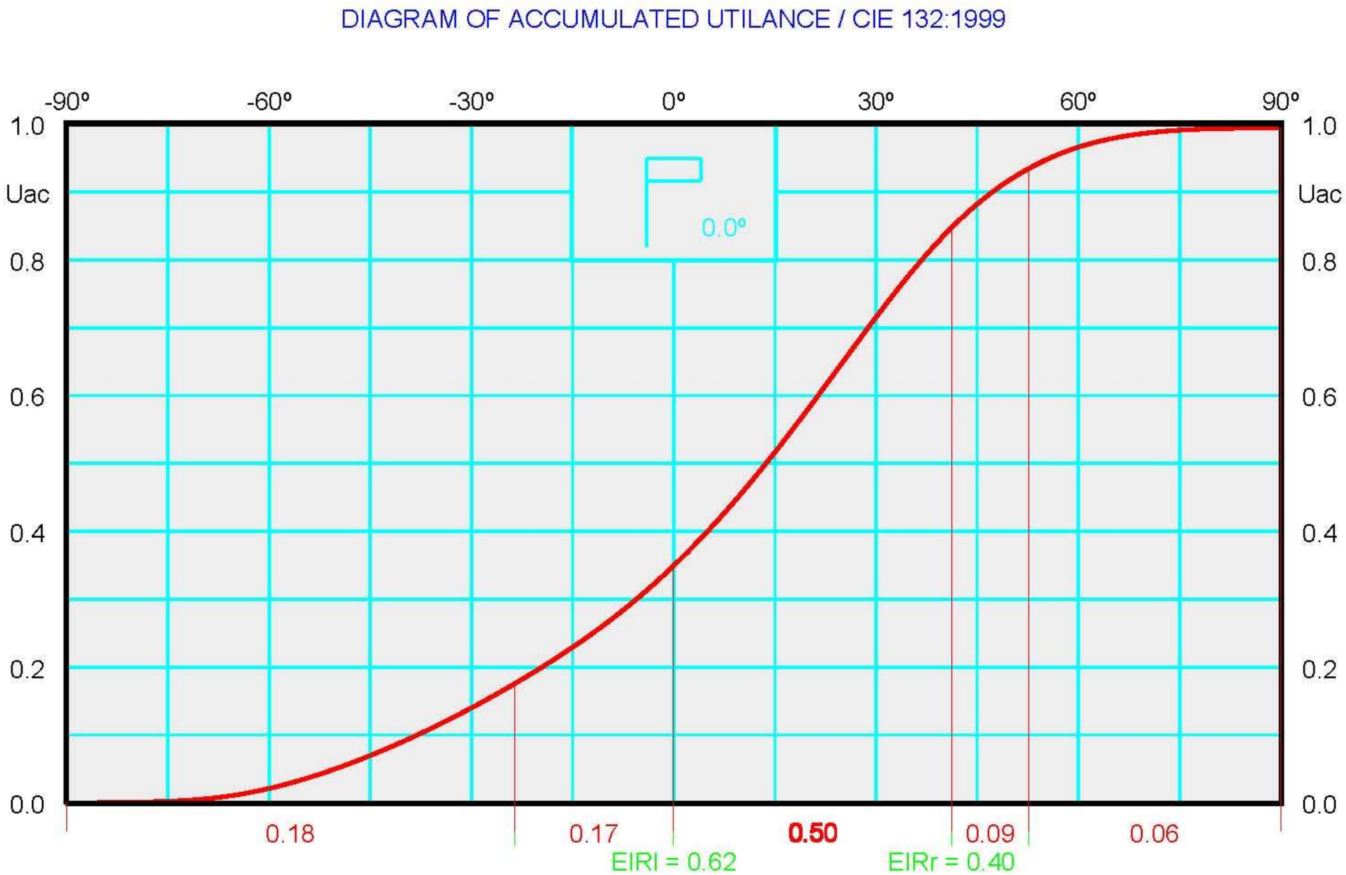




Accumulated Utilances,
(more modern conventional luminaire)







Accumulated Utilances, (modern LED luminaire)

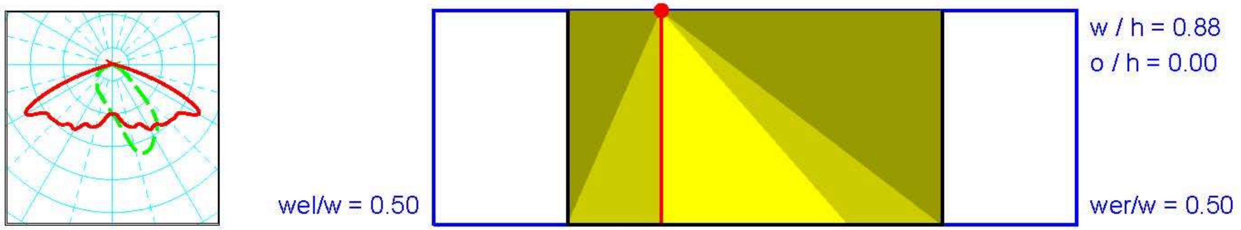
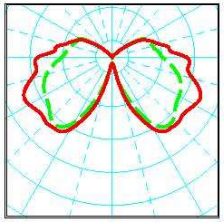
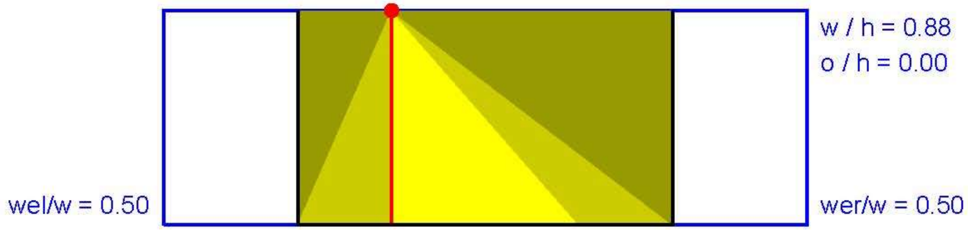
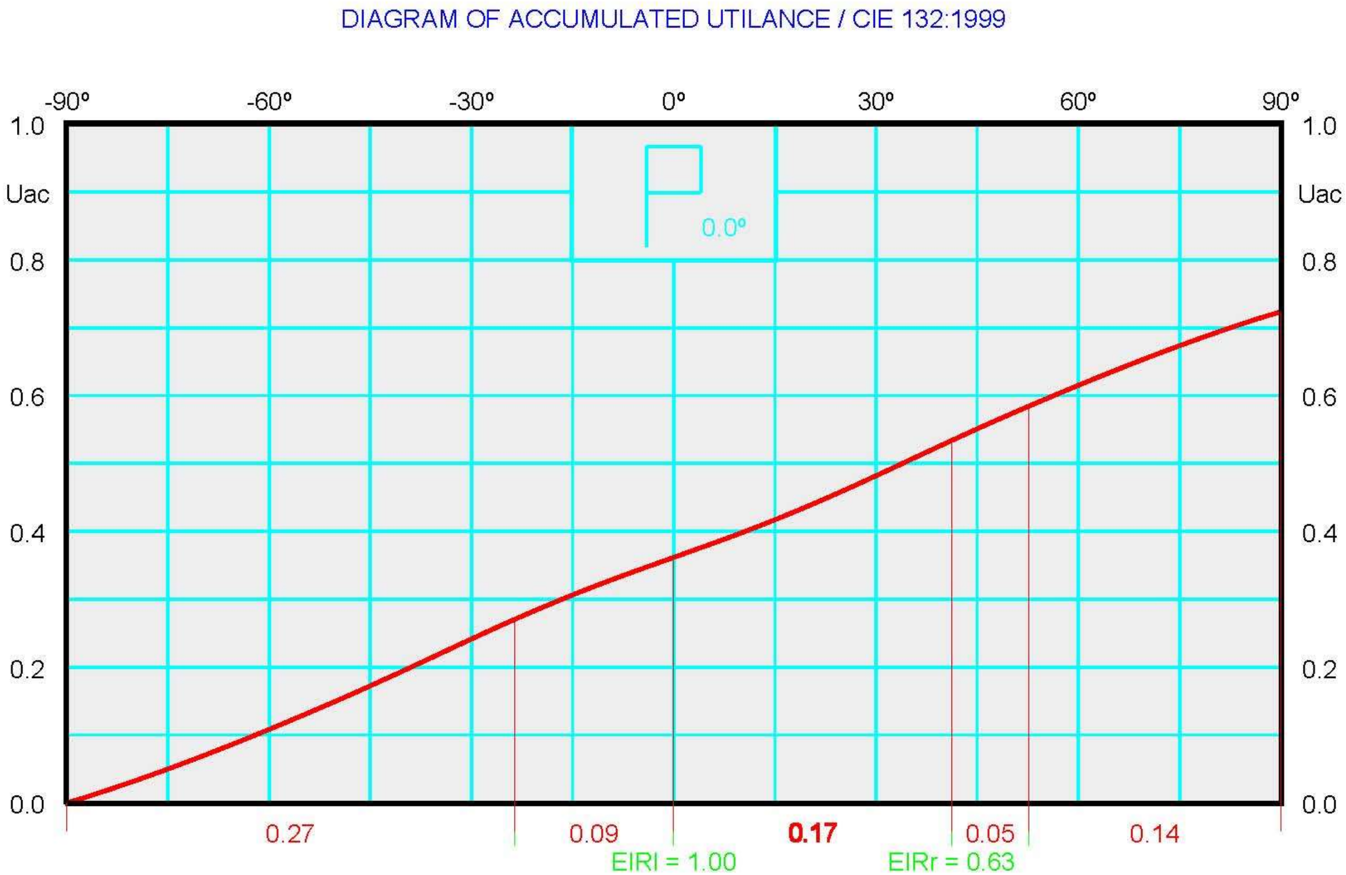


DIAGRAM OF ACCUMULATED UTILANCE / CIE 132:1999

Accumulated Utilances,
(direct/indirect road lighting lantern)

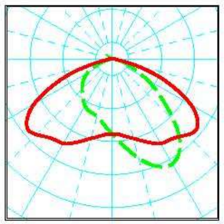


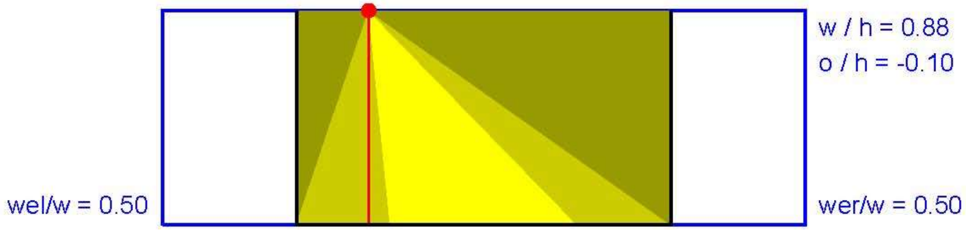


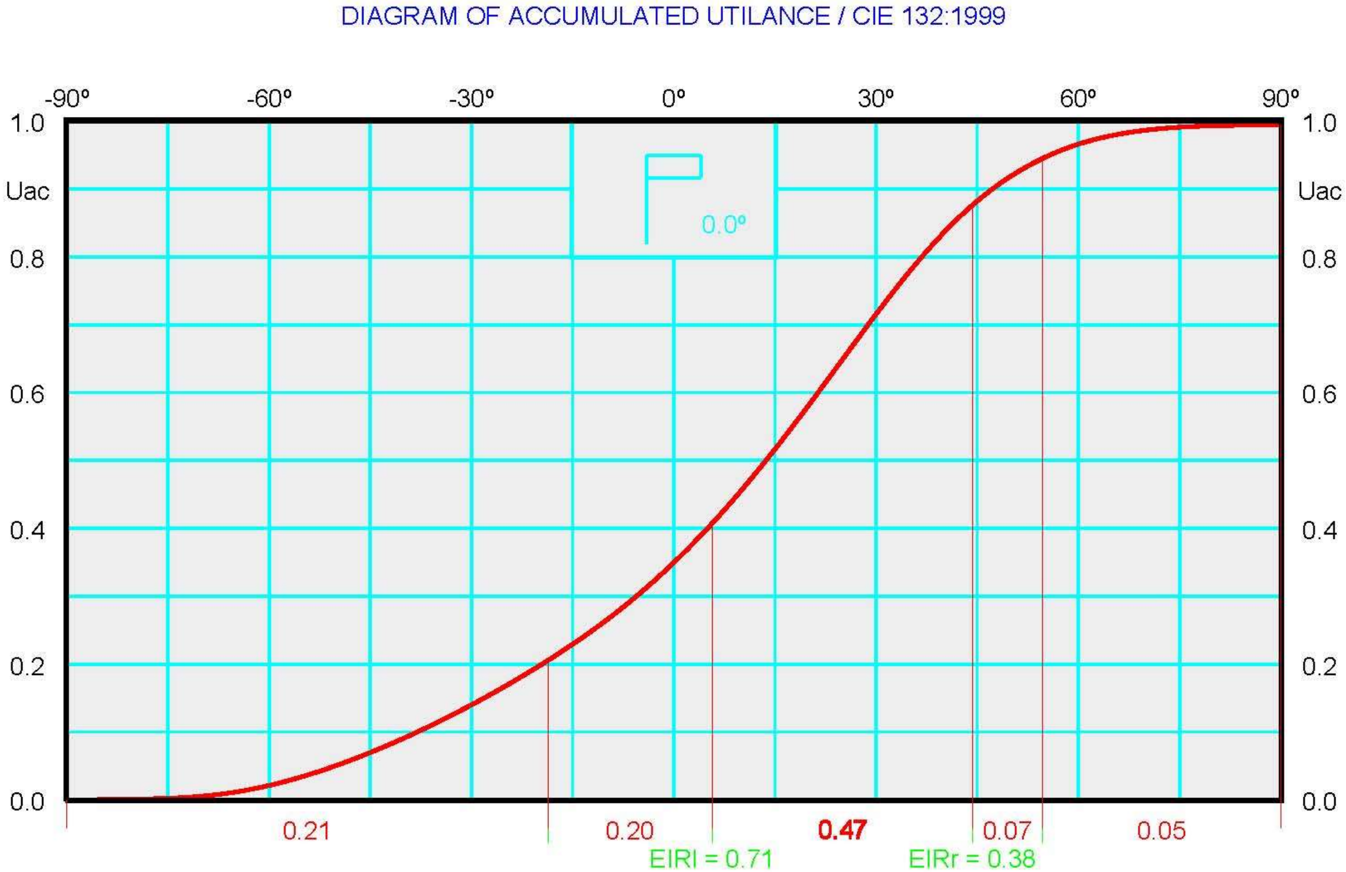


TAKING **COOPERATION** FORWARD

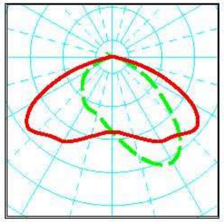
Accumulated Utilances, (variation of overhang, angle of tilt = 0°)

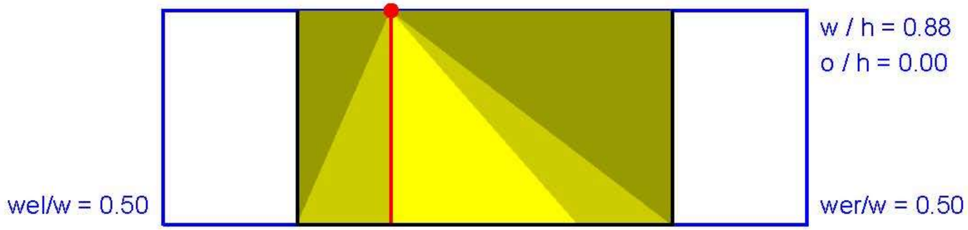


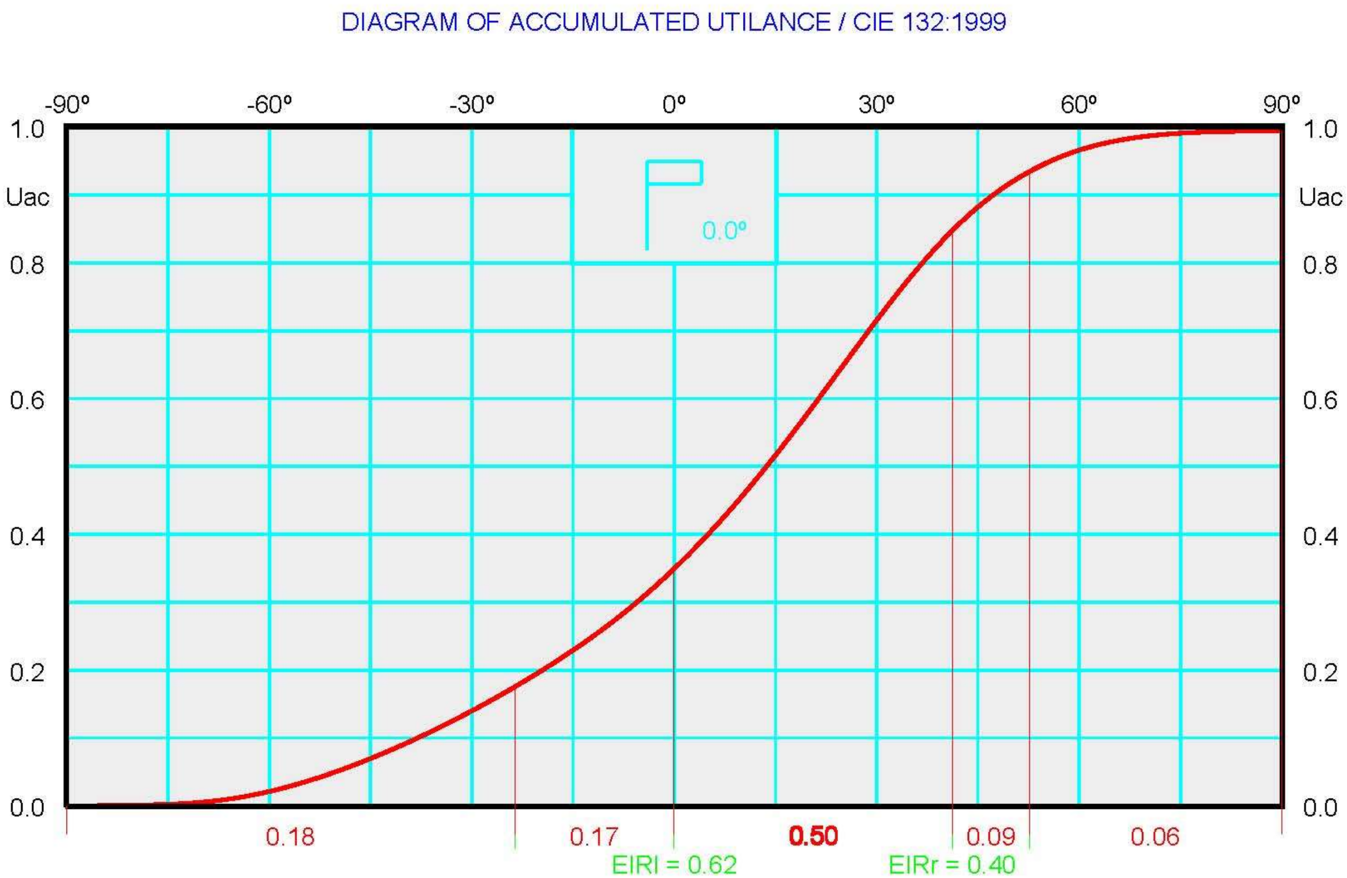




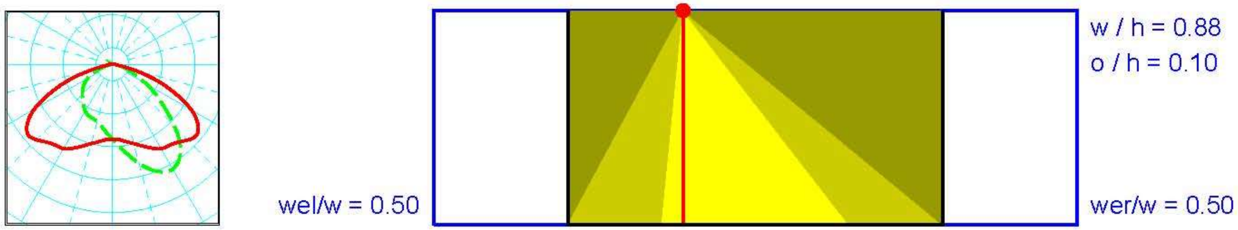
Accumulated Utilances, (variation of overhang, angle of tilt = 0°)

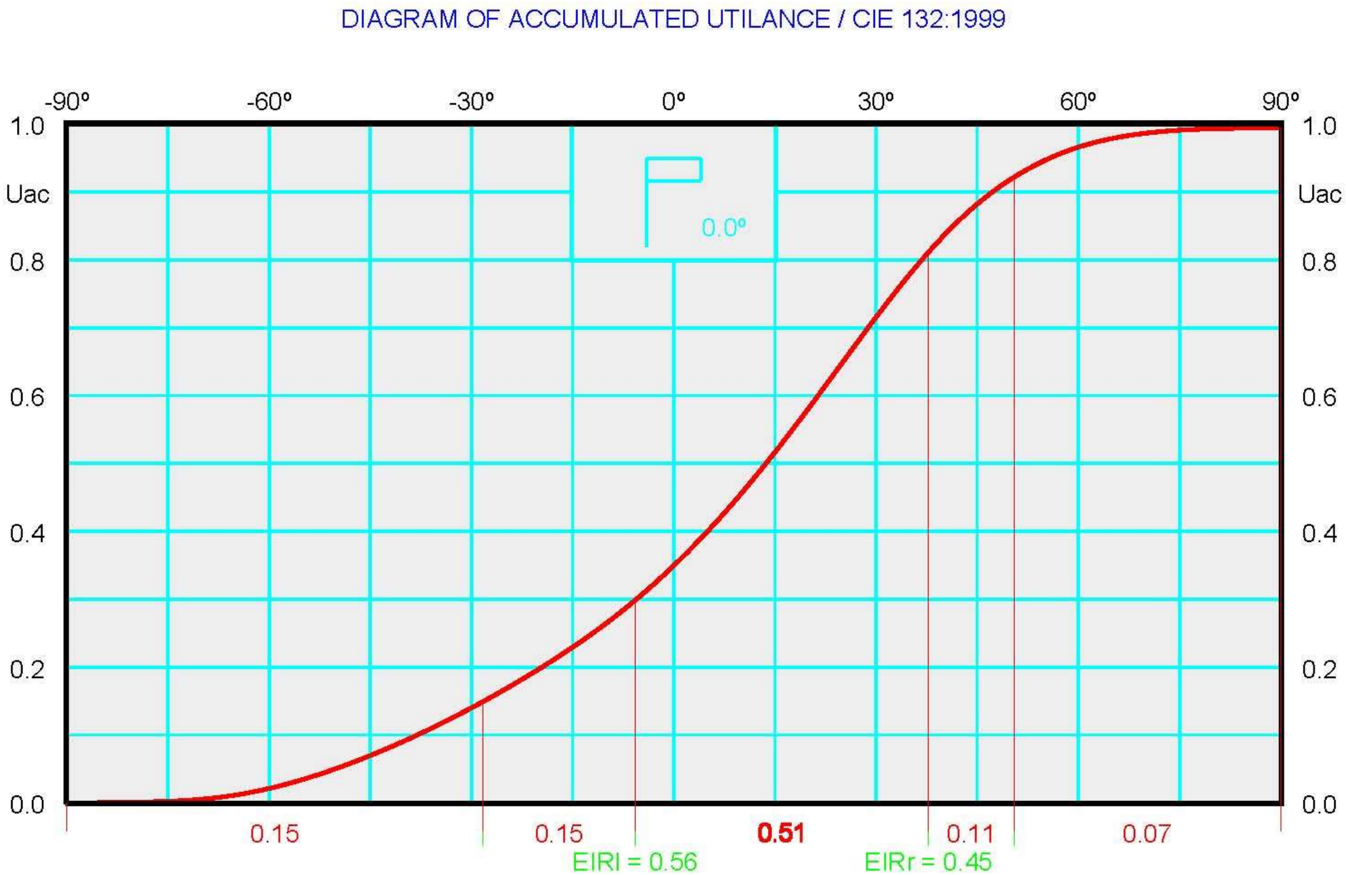






Accumulated Utilances,
(variation of overhang, angle of tilt = 0°)





Accumulated Utilances, (variation angle of tilt, overhang 0)

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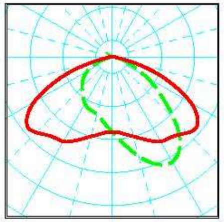
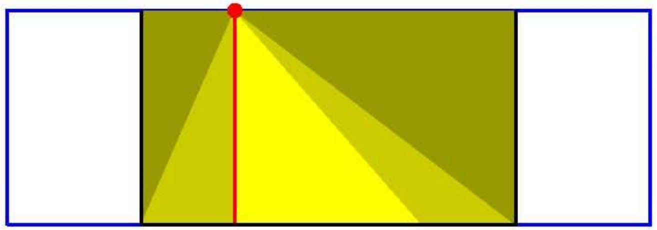
Dynamic Light



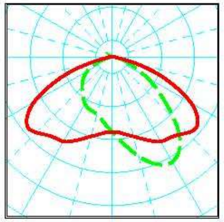
wel/w = 0.50

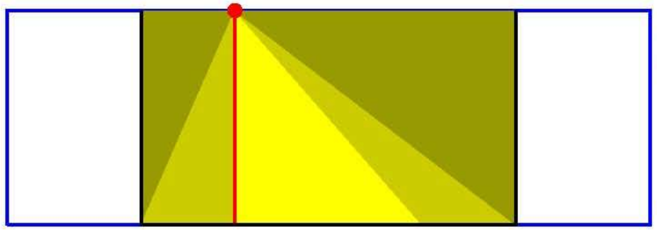


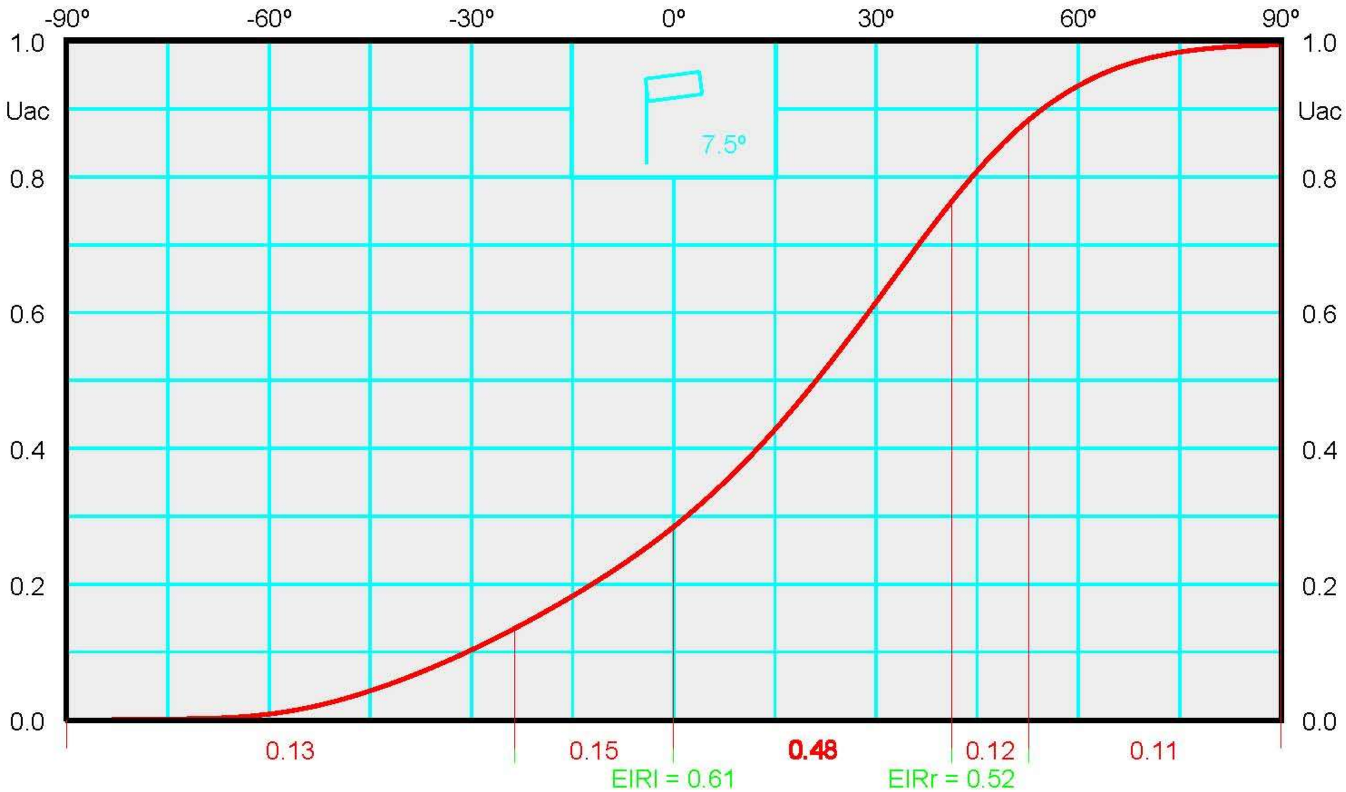
w / h = 0.88
o / h = 0.00
wer/w = 0.50

DIAGRAM OF ACCUMULATED UTILANCE / CIE 132:1999

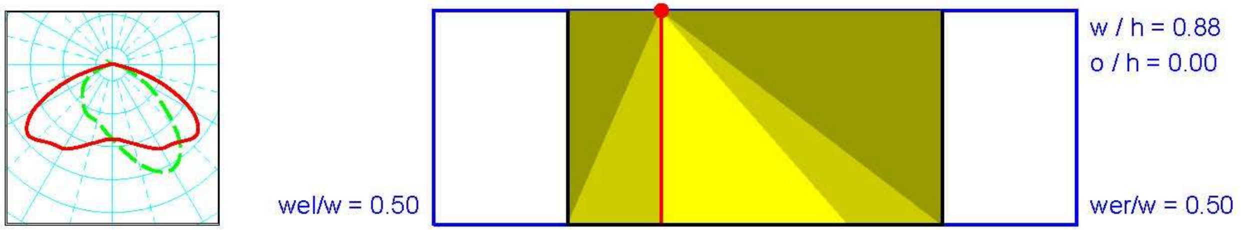
Accumulated Utilances,
(variation angle of tilt, overhang 0)

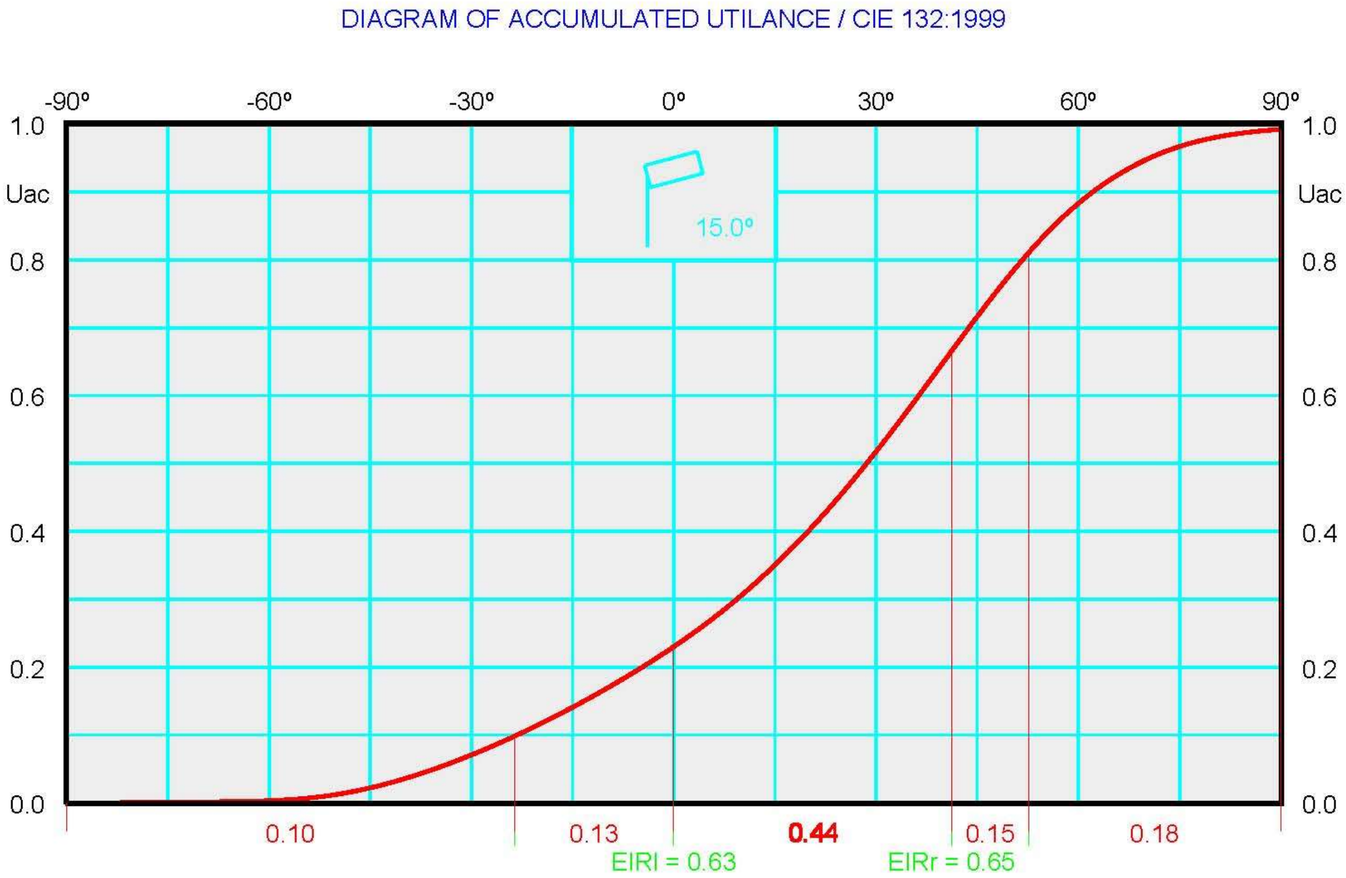




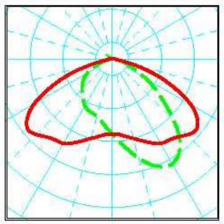


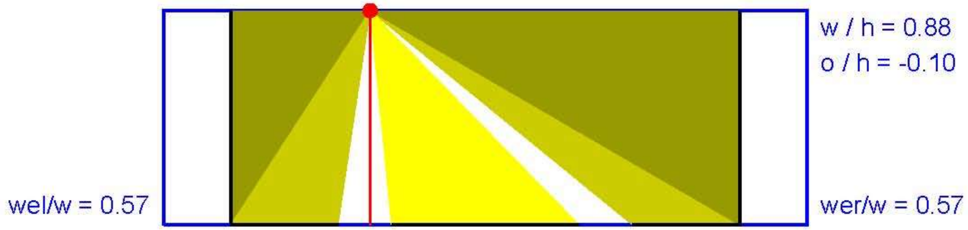
Accumulated Utilances,
(variation angle of tilt, overhang 0)

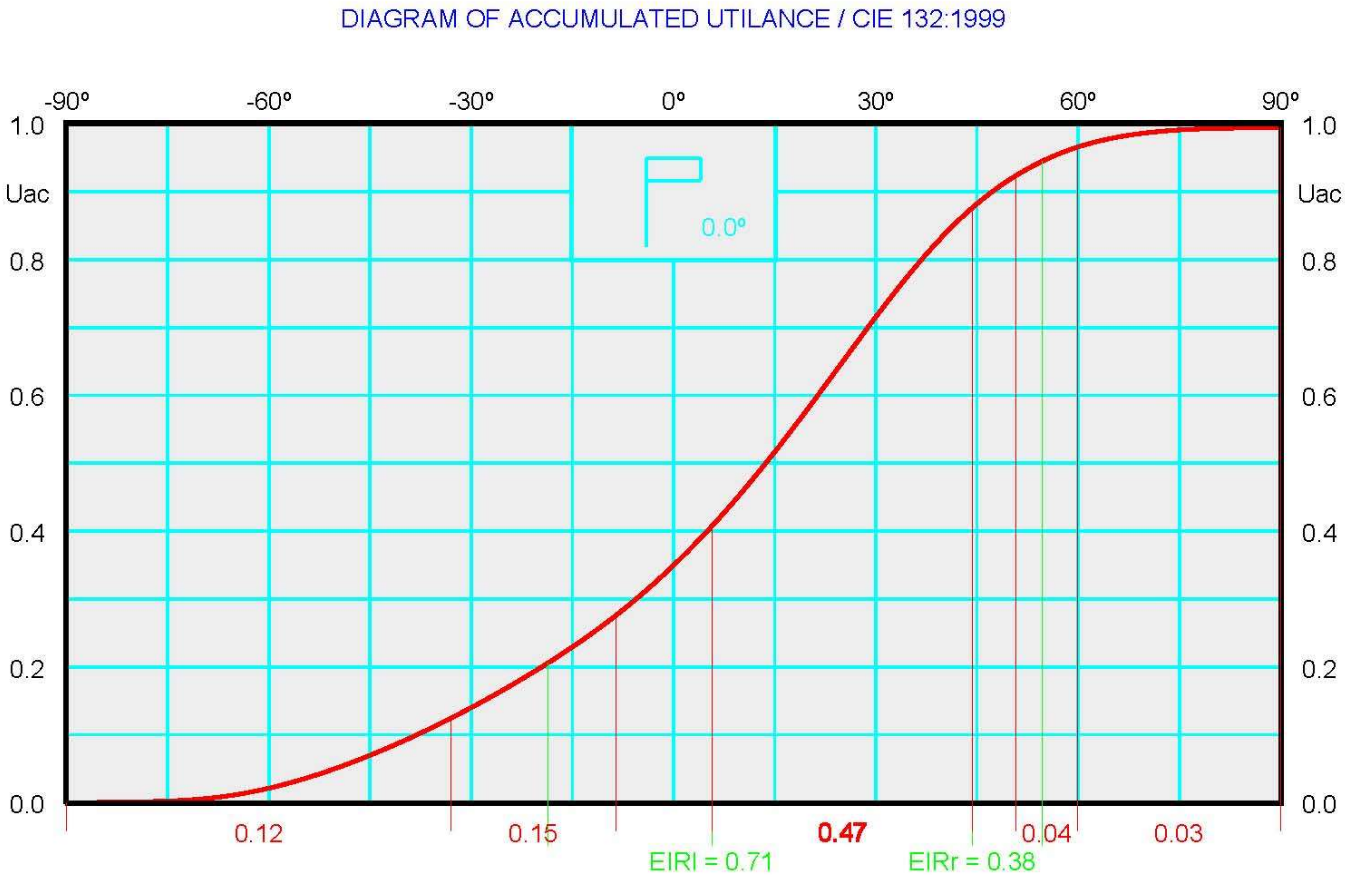




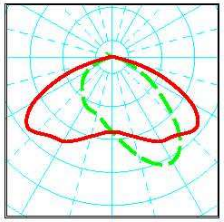
Accumulated Utilances,
(variation of overhang, tilt = 0°, separate path)

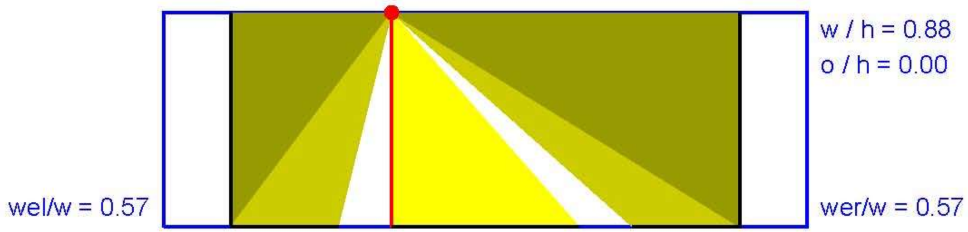


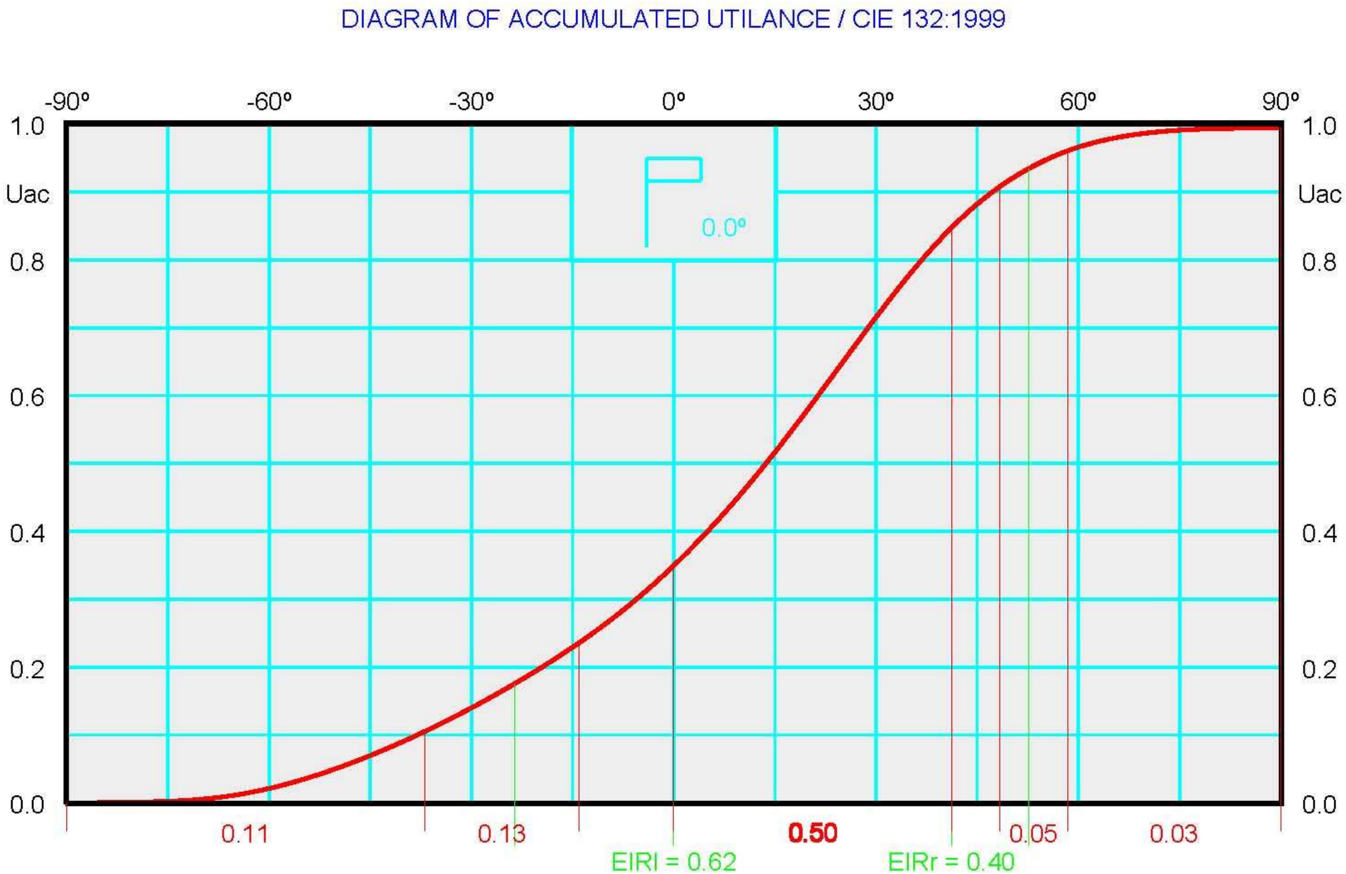




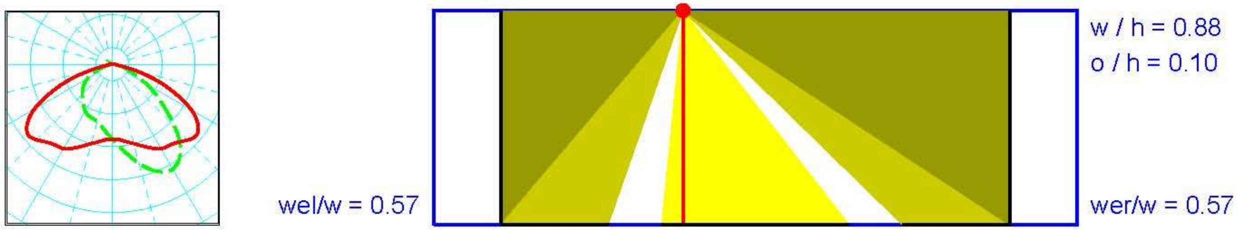
Accumulated Utilances,
(variation of overhang, tilt = 0°, separate path)

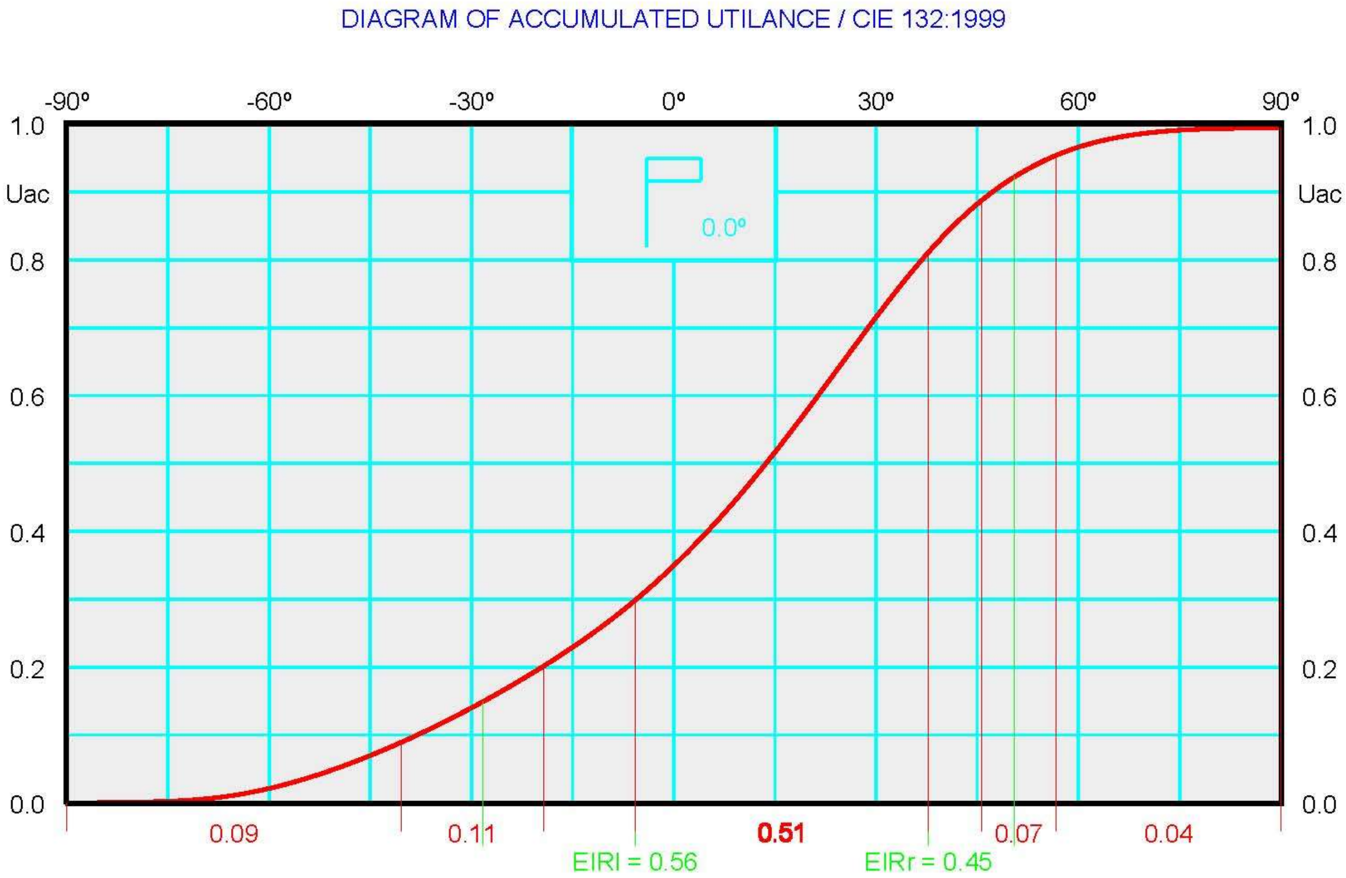




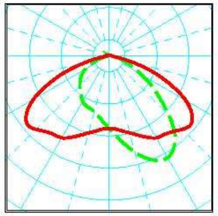


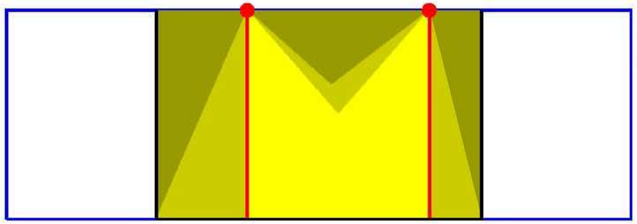
Accumulated Utilances,
(variation of overhang, tilt = 0°, separate path)

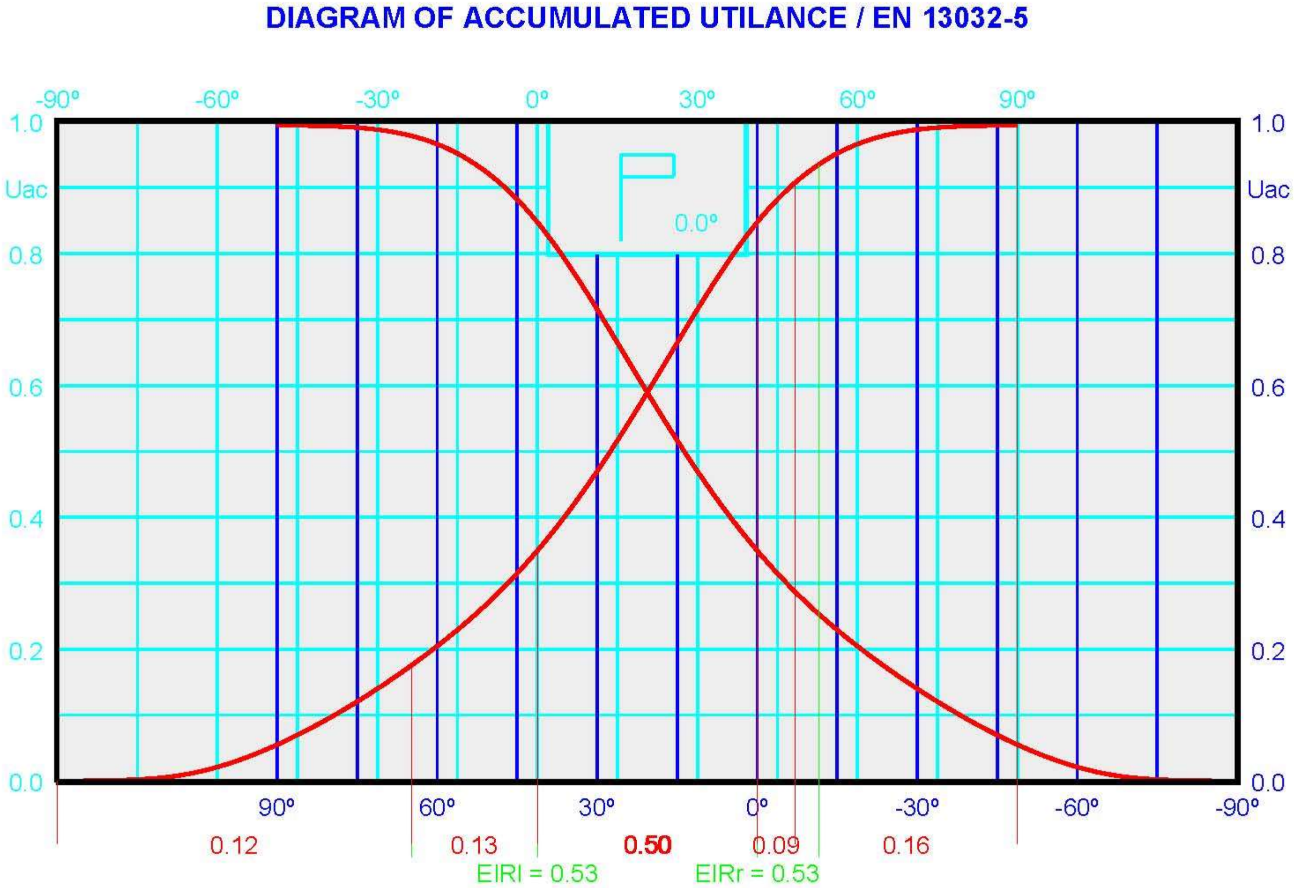




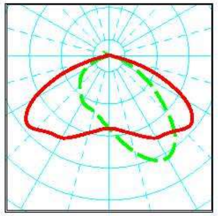
Accumulated Utilances, (opposite/staggered, variation of width of path)

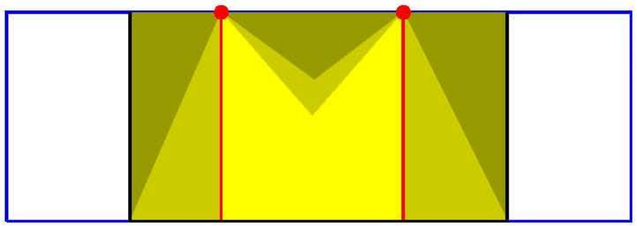


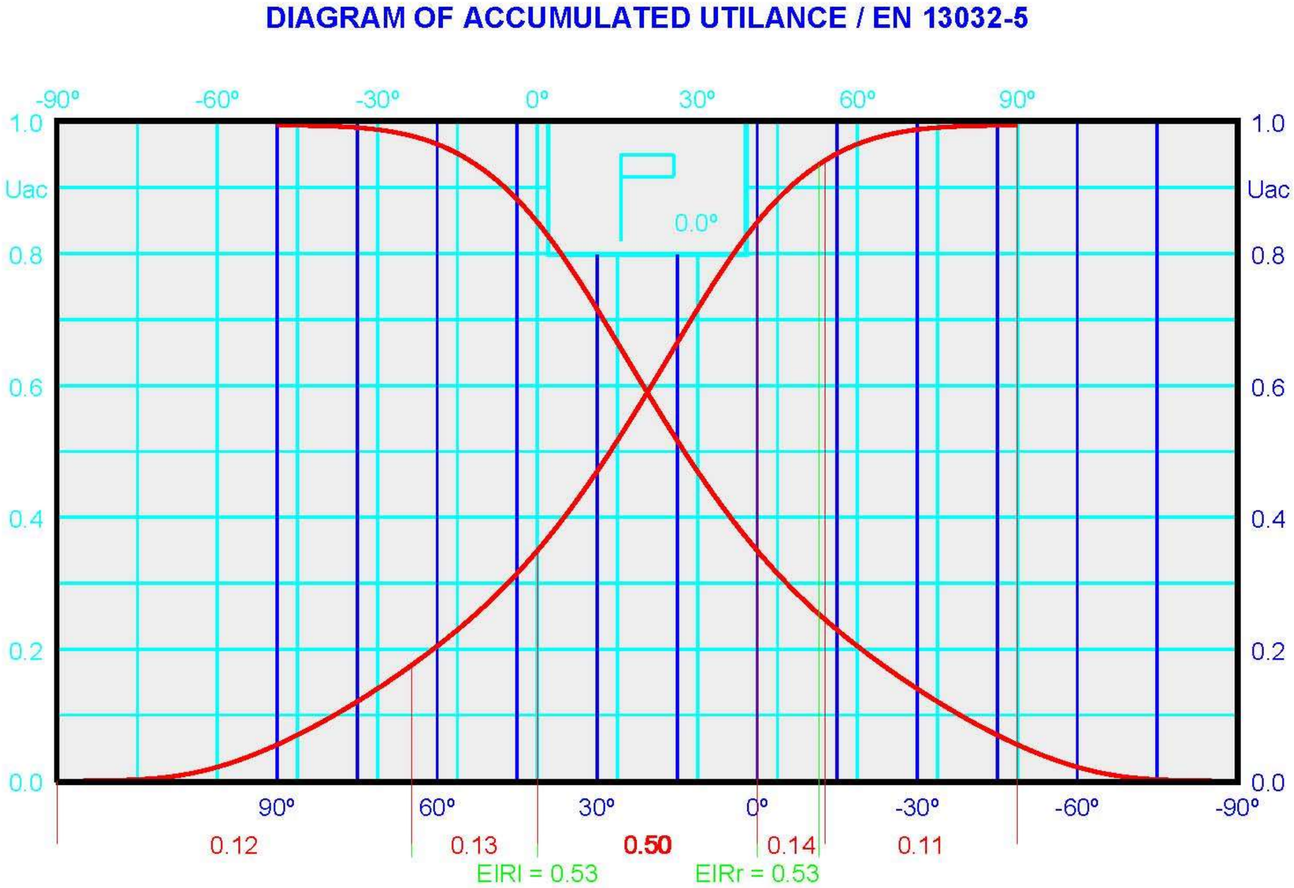




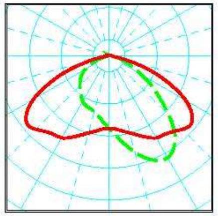
Accumulated Utilances, (opposite/staggered, variation of width of path)

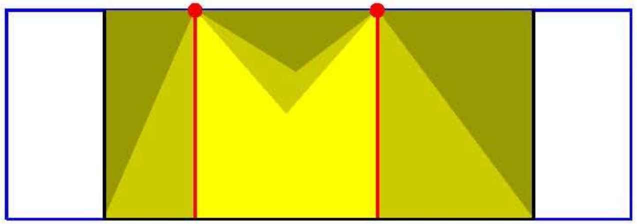


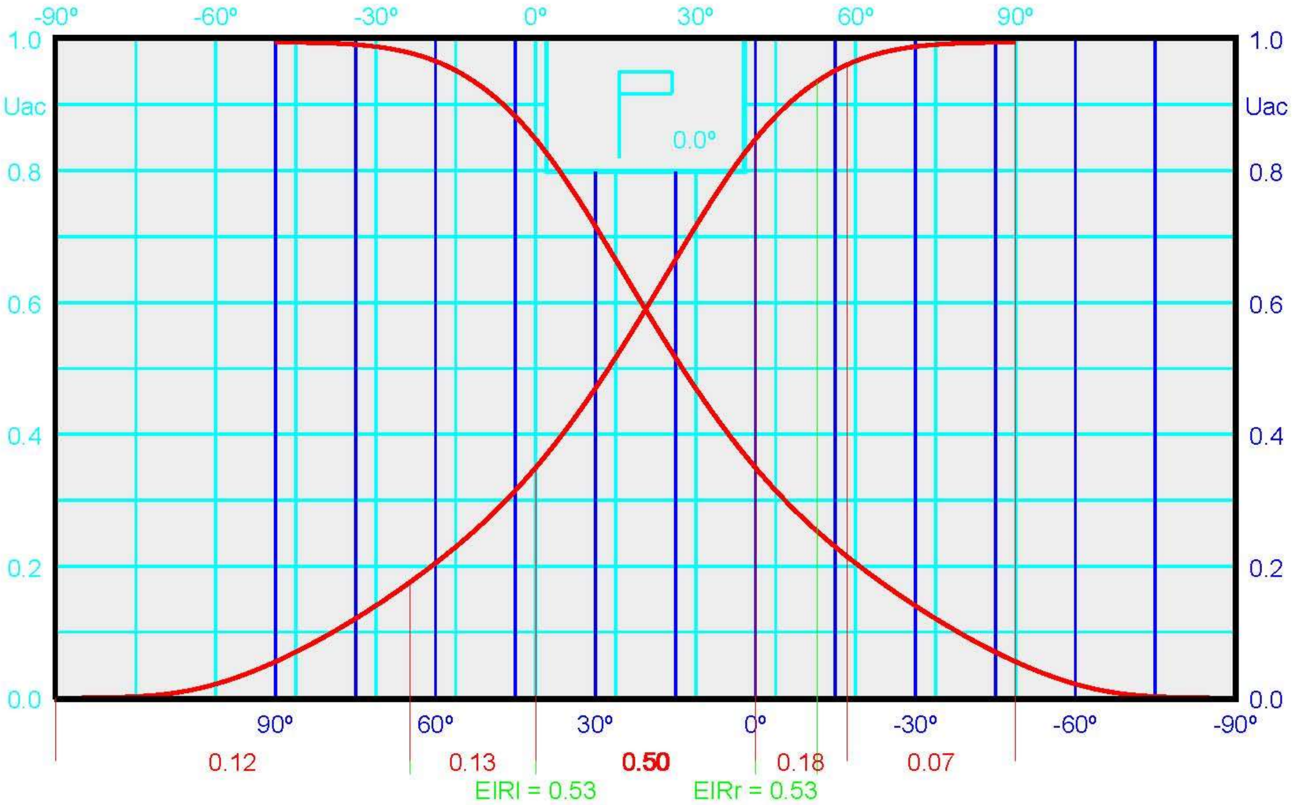




Accumulated Utilances, (opposite/staggered, variation of width of path)







Conclusions (I)

- The European Technical Report CEN/TR 13201-1:2014 “Road lighting - Part 1: Guidelines on selection of lighting classes” shows **some anomalies and simplifications** which are a hindrance to the transformation of this report into national recommendations, regulations or standards.
- In a number of countries (also participating in this INTERREG project) the national standards organizations have elaborated national standards on the selection of lighting classes.
- The **parameters to be taken into account** are generally related to the fixed geometry of the area under consideration, to the time dependent traffic use of the area, and to the time dependent influence of the surrounding environment.
- A functional or administrative classification and designation of roads could lead to a simplified selection procedure insofar as only some relevant time dependent parameters have to be considered.

Conclusions (II)

- If categorized roads are associated not only with fixed but also with in principal time dependent parameters, e.g. maximum traffic flow or ambient luminance, the comparison with the actual situation, possibly supported by a risk analysis, could lead to (usually) a reduction of the lighting level, i.e. the application of adaptive / dynamic lighting.
- Where the **pattern of variation in parameter values is well known**, such as from records of traffic counts on traffic routes, or can be reasonably assumed, as in many residential areas, a simple time based control system may appropriate. In other situations an interactive control system linked to real-time data may be preferred.
- **All in all the application of adaptive / dynamic lighting is regarded as a very useful tool to reduce energy consumption, light pollution, and CO2-emission while keeping road safety and security at an appropriate level.**

Thank you very much for your attention!