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Road lighting

Part 4: Methods of measuring lighting performance

National foreword

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European foreword

This document (EN 13201-4:2015) has been prepared by Technical Committee CEN/TC 169 "Light and lighting", the secretariat of which is held by DIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by June 2016 and conflicting national standards shall be withdrawn at the latest by June 2016.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CEN [and/or CENELEC] shall not be held responsible for identifying any or all such patent rights.

This document supersedes EN 13201-4:2003.

The main technical changes in this version are:

— The definition of different aims of measurement with peculiar requirements in order to optimize the instrument characteristics, measurement cost and time;

— A deeper comparison between static and dynamic measurement requirements;

— Addition of specific requirements for ILMD (Image Luminance Measuring Device) when used as luminance meter;

— Evaluation of measurement uncertainty;

— Comparison with requirements or design expectation carried out considering the expanded measurement uncertainty of the measure;

— Addition of guidelines for the measurement of Threshold Increment and of Edge Illuminance Ratio;

— Suggestion for an algorithm for the evaluation of tolerances in road lighting installation design;

— Description of the concept of particular parameters in order to consider measurements carried out in condition different from the normative ones;

— Description of an improved convention for symbols of photometric quality parameters in order to avoid confusion between values of the same parameter but with different meanings;

— Measurement systems for adaptive road lighting are considered;

— Guidelines for the measurement uncertainty evaluation are given.

This document EN 13201-4 has been worked out by the Joint Working Group of CEN/TC 169 "Light and lighting" with CEN/TC 226 "Road Equipment", the secretariat of which is held by AFNOR.

EN 13201, *Road lighting* is a series of documents that consists of the following parts:

— *Part 1: Guidelines on selection of lighting classes* [Technical Report]*;*

— *Part 2: Performance requirements;*

— *Part 3: Calculation of performance;*

— *Part 4: Methods of measuring lighting performance* [present document]*;*

— *Part 5: Energy performance indicators.*

According to the CEN-CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.

Introduction

The purpose of Part 4 of this European Standard is to:

a) establish conventions and procedures for the characterization based on measurements of road lighting installations considering the photometric quality parameters, i.e. the set of quantities that characterize a lighting class, specified in Part 2;

b) give advice on the use and selection of luminance meters and illuminance meters for this particular application;

c) specify measurement requirements according to the aims of the measurement and expected accuracy;

d) establish conventions for evaluating the measurement uncertainty of involved parameters;

e) give information on the application of tolerance analysis in the design of the lighting installation.

A non-exhaustive list of possible measurement aims is:

f) verification of compliance with standard requirements;

g) verification of compliance with design expectations;

h) road lighting installation monitoring, e.g. for maintenance purposes;

i) road lighting installation control, e.g. for optimizing energy saving;

j) investigation of discrepancies between real lighting conditions and design expectations.

The conventions for observer position and location of measurement points are those adopted in EN 13201-3. However, relaxation from these is permitted especially where the measurements are used for monitoring the performance of a road lighting installation, to control its performances or other purposes or when different conditions are specified in the road lighting installation design.

Conditions, which can lead to inaccuracies, are identified and precautions are given to minimize and quantify these.

This standard should be used to write measurement procedures for the characterization of road lighting installations.

Criteria for deciding when measurements should be done, on the purpose of measurements and on how the measurement results shall be used fall outside the scope of this standard.

1 Scope

This European Standard specifies measurement conditions and procedures for measuring the photometric quality parameters of road lighting installations, i.e. the quantities that quantify their performances in accordance with EN 13201-2 lighting classes.

Parameters used for quantifying the energy performance of road lighting installations are not considered.

A methodology to evaluate the road lighting performances considering tolerances in the design parameters is described in the informative Annex A.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12665, *Light and lighting — Basic terms and criteria for specifying lighting requirements*

EN 13032-1, *Light and lighting — Measurement and presentation of photometric data of lamps and luminaires — Part 1: Measurement and file format*

EN 13201-2, *Road lighting — Part 2: Performance requirements*

EN 13201-3:2015, *Road lighting — Part 3: Calculation of performance*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN 12665 and the following apply.

3.1
automatic measuring system for control purpose
automatic system used to generate a control signal, correlated to one or more measured photometric parameters that can influence the operating conditions of a road lighting installation

Note 1 to entry: Metrological parameters, such as measurement repeatability and stability, generally are the main characteristic of the system.

3.2
dynamic measurement system
measurement system that moves along the road surface to carry out the measurement

3.3
static measurement system
measurement system that does not move when in service

3.4
parameter (normative)
quantity defined in EN 13201-2 following calculation rules of EN 13201-3

Note 1 to entry: The value of the parameter can:

a) give standard requirements;

b) give values effectively required by the road authority (design expectations). These values can differ from values given in EN 13201-2;

c) be evaluated using the appropriate algorithm (based on a physical model of light propagation in the environment) as specified by EN 13201-3;

d) be measured following conditions that fit those specified in EN 13201-3 for the points of the grid and, if necessary, for the position of the observer and verifying if the influence of the metrological characteristics of the measuring instrument is compatible with the physical definition of the parameter.

3.5
particular parameter
quantity calculated, measured or evaluated in accordance with given and well-defined conditions, but different to those specified in EN 13201-3

Note 1 to entry: The set of conditions shall be described with the measurement results.

3.6
luminance (normative)
L
luminance of an elementary surface centred at a given point when viewed from the standard observation position according to EN 13201-3

Note 1 to entry: The luminance is expressed in candela per square metre.

3.7
luminance (particular)
L_p
luminance of a surface centred at a given point when viewed from a specified observation position and/or specified conditions highlighted using the subscript p

Note 1 to entry: The luminance (particular) is expressed in candela per square metre.

3.8
extended uniformity
a particular parameter introduced to mathematically analyse the influence of non-homogeneity of the environment or of the road surface

Note 1 to entry: This is particularly useful when dynamic measurement systems are used and the presence of non- homogeneity cannot be evaluated before the measurement.

Note 2 to entry: Extended uniformity is discussed in the informative Annex B.

3.9
set measurement
measurement carried out in an installation to determine the values of parameters used by an automatic measuring system for control purpose

3.10
image luminance measuring device
ILMD
digital electronic device, equipped with a lens, an adequate photometric matching filter, a sensor made by a matrix of detector (pixel), and calibrated for measuring the luminance distributions of the framed scene

Note 1 to entry: Every pixel is calibrated to determine the luminance values of the space imaged on its surface by the lens system.

Note 2 to entry: The matrix of pixel is generally realized with CCD (charge coupled device) or CMOS (complementary metal oxide semiconductor) sensors.

Note 3 to entry: In literature different terms may be found to describe ILMD such as multi-channel luminance meter, luminance mapper, array (or matrix) luminance meter, video photometer, photo luminance meter, CCD luminance meter, luminance camera, multidirectional luminance meter, spatial luminance profile device.

3.11
split detector system
a method of measuring horizontal illuminance using couple/s of detectors, the first detector of every couple measures light from the hemisphere in the forward direction, the second one measures light from the hemisphere in the rearward direction

Note 1 to entry: This method is usually applied in dynamic measurement system where one detector is mounted on the front of the vehicle and the other on the rear of the vehicle.

Note 2 to entry: The point illuminance value is obtained by summing the readings of the two detectors at the same spatial point.

3.12
adaptive lighting
temporal controlled changes in luminance or illuminance in relation to traffic volume, time, weather or other parameters

4 Symbols and abbreviations

EN 13201-3 lists the normative photometric quality parameters of a road lighting installation.

For particular measurement purposes, in addition of normative parameters, a set of particular parameters is described in the informative Annex B. In accordance with the measurement aims and measurement procedures, the person responsible for the measurement decides if it is necessary to use these parameters.

When necessary, to clearly specify with a symbol the meaning or the measurement conditions linked to a parameter the conventions described in the normative Annex C shall be adopted.

5 Preliminary information of road lighting system measurement

5.1 Aims of measurements

At least four different aims require the measurement of the photometric quality parameters of a road lighting system:

Measurements at the final testing phase: measurements carried out during the final testing/commissioning phase of the road lighting installation, to verify the compliance with standard requirements and/or with design expectations. These results can be used for the road lighting installations formal approval.

Measurements during the road lighting lifetime: measurements carried out at pre-determined intervals during the road lighting lifetime, to quantify the degradation of the lighting performance and to define the need for maintenance or to verify the compliance of the road lighting installation with the standard requirements or design expectations, generally based on maintained values.

Measurements for adaptive road lighting: measurements carried out continuously or at pre-determined intervals to control the luminous flux of luminaires in adaptive road lighting, where the installations performance is kept at the given value within a given tolerance.

Measurements for investigation of discrepancies: measurements carried out as and when required to investigate discrepancies between measures and design expectations or environment influence.

For every aim different measurement procedures, requirements and metrological characteristics of instruments shall be considered.

The main part of the standard considers requirements for measurement at the final testing phase and during the road lighting lifetime. Peculiarities or additional requirements for measurements for adaptive road lighting are given in the normative Annex D and for investigation of discrepancies in the informative Annex E.

The set measurement (see 3.9) is considered as a peculiar measurement that shall follow requirements for measurement at the final testing phase.

Except for the set measurement, when measurement results need to be compared they shall be carried out considering the same set of measurement points and, if required, observer position.

Measurements shall be carried out following a detailed operating procedure that shall consider the standard requirements or design expectations, describes the evaluation of measurement uncertainty (see informative guidelines in Annex F), specifies the conditions of its applicability and considers practical aspects (see informative guidelines in Annex G).

The objectives of the measurement shall be written in the test report (see Clause 9 and the informative Annex H).

NOTE An existing installation can have its design documentation missing. In this case measurement can be done according to tender specifications.

5.2 Measurement procedures and selection of photometric instruments

5.2.1 Static versus Dynamic measurements

Measurements can be done with either static or dynamic measurement systems. For a given measurement aim (see 5.1), the selection of the adopted system shall be done considering the required accuracy of the results and other constrains that can rise from safety reasons, local and temporary conditions and/or tender requirements.

A dynamic measurement system can measure the total length (or surface) of a road lighting installation in a more reasonable time than a static measurement system. This peculiarity can be useful when the homogeneity of performances of the road lighting installation shall be investigated or when an entire road network has to be evaluated at a given instant.

NOTE Guidance on design and use of dynamic measurement systems is given in CIE 194:2011.

5.2.2 General requirements on measurement procedures and on measurement devices

The measurement procedures adopted shall be suited to the purpose of the measurements.

For a given measurement aim, the maximum acceptable value of the expanded measurements uncertainty shall be defined considering national or tender requirements and upon the evaluation of the influence this uncertainty can have on the decision taken using the measurement results or on the power consumption of the road lighting installation or any other parameters defined in EN 13201-5.

All instruments shall be calibrated in the ranges used to assure their metrological traceability.

NOTE 1 Calibration performed by an EN ISO/IEC 17025 accredited calibration laboratory guaranties this requirement.

The metrological characteristics of the instruments used shall be suited to the purpose of the measurements. Luminance shall be measured with a luminance meter which has a performance suitable for the purpose of the measurements. Illuminance shall be measured with an illuminance meter which has a performance suitable for the purpose of the measurements:

— for the measurement of horizontal and vertical illuminance a photometer head for the measurement of planar illuminance is required;

— for semicylindrical or hemispherical illuminance a photometer head designed for this purpose is required.

The instruments metrological performances shall be evaluated for the specific conditions of the application.

Therefore if needed, the calibration and photometric characteristics of the detector used shall be corrected taking account of the ambient temperature and humidity conditions during measurements and the spectra emitted in the visible region by the luminaires.

Instruments used for measurement of photometric parameters shall be characterized in accordance with EN 13032-1 for all the relevant parameters and their influence shall be considered in the uncertainty evaluation model.

NOTE 2 Guidance on the performance of illuminance and luminance meters is given in CIE S 023/E:2013.

5.2.3 Specific requirements for luminance meter

For every type of luminance meters the influence of light sources external to the framed field shall be considered.

For every type of luminance meter, in every case of grind point measurement the angular subtense of the measured road surface shall be not be greater than 2 min of arc in the vertical plane and not greater than 20 min of arc in the horizontal plane. The minimum angular subtense shall be no lower of 1 min of arc.

NOTE 1 The field of calculation specified in EN 13201-3 commences 60 m from the observer. This means that to prevent overlap of the measurement areas as seen through a luminance meter set at this distance, the maximum value of angle of the measurement cone has the value indicated above.

NOTE 2 The minimum value of the angular subtense consider a conventional visual acuity of 1 min of arc.

If the measurement is carried out at a closer distance respect to the nominal positions of the observer given in EN 13201-3 (see 7.2.1) it is recommended that the measurement cone of the luminance meter should not exceed 30 min of arc, and the size of the measurement area on the road should not be greater than 0,5 m transversely and 2,5 m longitudinally.

5.2.4 Additional requirements for ILMD

For ILMDs the influence of shutter repeatability, pixel saturation and ghost images shall also be considered.

If an ILMD is used the luminance for each grid point may be determined by averaging the reading of adjacent pixels. In every case the conditions on the angular subtense of the measured surfaces shall comply with requirements given in 5.2.3.

5.3 Measurement uncertainty evaluation

The measurement uncertainty can be considered as having three groups of components:

a) Those concerning the metrological characteristics of the measurement system and the influence of measurement procedures;

b) Those concerning the influence of the nominal characteristics and layout of the road lighting installation being measured;

c) Those concerning the influence of the instantaneous characteristics of the road lighting installation being measured, and of the weather and environmental conditions.

These three groups shall be separated because the last one can change significantly from one measurement to another, while the influence of the measurement system can remain substantially constant.

The various sources of measurement uncertainty can be classified as:

a) accuracy of measurement instruments;

b) accuracy of the coordinate reference of the measured point or area (if relevant);

c) influence of the measurement procedure;

d) influence of data elaboration methods;

e) road lighting installation characteristics and stability of the photometric parameter’s during measurement;

f) electrical power supply conditions;

g) weather conditions (temperature, relative humidity, wind velocity, etc.);

h) environmental conditions (presence of trees, shielding objects, disturbing light sources, other lighting installations, etc.).

For practical reasons this European Standard does not require the evaluation of the uncertainty contribution of the last three, but only a description in the test report of their conditions, because:

i) they are not usually under the control of the measurement team;

j) their evaluation or measurement can be difficult or expensive;

k) the road lighting installation should normally be evaluated in real working conditions that do not need to be quantitatively known in detail;

l) the influence of these matters on the measured illuminance or luminance value is generally not known and it is likely to be impossible to determine without a laborious and expensive set of measurements.

If point values or uniformities are given in the test report, the influence of the detector misalignment (e.g. the detector surface is not in the nominal position with respect to grid points) for illuminance measurements or position and dimensions of the framed surface for luminance measurements shall be considered when evaluating measurement uncertainties. This correlation is a characteristic of the road lighting installation (spatial variation of illuminance or luminance near the point due to non-uniform light distribution) and not of the measurement system or measurement procedures.

This contribution to the measurement uncertainties need not be considered for average values.

Guidelines for the evaluation of measurement uncertainty in road lighting installation characterization are given in the informative Annex F.

NOTE Guidance on the calculation of measurement uncertainty is given in ISO/IEC Guide 98-1:2009 and ISO/IEC Guide 98-3:2008.

5.4 Measured zones

The measurements shall consider the entire length of the road lighting installation and all its operating conditions (lighting classes).

If the road lighting installation characteristics are designed as constant for the total length of the installation, it is possible to select a relevant number of zones and to carry out measurements only in these zones (measured zones). In this case a description of the reasons, justifications and consequences of this choice shall be written in the test report.

NOTE One of the most common reasons for the selection of particular measured zones is the supply voltage drop in the power supply electrical line.

5.5 Measured parameters

The road geometrical parameters in the measured zone (column spacing, carriage and lane width) shall be measured or known to allow for defining the reference for point coordinates and the nominal values of point coordinates.

The position, inclination and orientation of the sensitive surface of the illuminance meter (for illuminance measurement) or of the position of measured surface (for luminance measurement) with respect to the nominal grid points shall be recorded in the test report.

For illuminance measurement the z coordinate (height of the light sensitive surface of the detector with respect to the road surface) shall also be specified.

NOTE These parameters are specified using their nominal value and tolerances, or the measured values with uncertainty.

Measurement *for the verification of compliance with standard requirements* shall consider all the photometric quality parameters for the pertinent lighting class/classes.

A reduced set of parameters may be adopted if agreed with the purchaser or operator and if this choice is described in the road installation design.

Measurement *for the verification of compliance with design expectation* shall consider a congruent set of parameters as specified and evaluated in the road lighting installation design.

EXAMPLE This set can specify the measurement of illuminance in grid points instead of the road surface average luminance and the calculation of uniformities considering these values.

The following additional points shall be described in the test report:

a) electrical power supply conditions,

b) weather and environmental conditions,

and shall be measured if requested as part of a tender specification or required as part of a pertinent standard (see Clause 8).

If tender specification or pertinent standard require the measurement of illuminance, as a preliminary verification step for M lighting classes, point illuminances at the same points of the grid used for luminance calculation shall be calculated for M lighting classes and illuminance measured at the same points.

If M lighting classes (see EN 13201-2) are considered and the project has a tolerance analysis (see the informative Annex A) tender specification may restrict the verification of compliance with standard requirements to the illuminance verifications only.

5.6 General information regarding measurements during the lifetime of the lighting installation

Measurements during the road lighting lifetime are usually carried out before or after installation maintenance, in accordance with design requirements.

A limited set of measured parameters and simplified measurement geometry may be selected in accordance with the design specifications or tender requirements.

The determination of some parameters can even be avoided, such as the verifications of the electrical working conditions of the installation, unless requested as part of a tender specification or required as part of a pertinent standard.

If measurements are carried out at pre-determined intervals or periodically to quantify the degradation of the lighting performance they may be done using simplified procedures. Different set of parameters or geometries may be measured but at least one parameter with a given geometry shall be measured for comparison purpose each time measurements are taken.

Correlation between the parameters measured in these conditions and the normative parameters shall consider previous measurements or specific measurement conditions describe in the road lighting installation design. However, all measurements shall be carried out in a compatible way each time monitoring is carried out.

5.7 Comparison with requirements

All comparison of measured results with standard requirements or design expectations shall be carried out considering the expanded measurement uncertainty of the measure:

a) for parameters that require a value greater or equal to a given level, the lower limit of the coverage interval of the expanded measurement uncertainty shall be greater or equal to the given level;

b) for parameters that require a value lower or equal to a given level, the upper limit of the coverage interval of the expanded measurement interval shall be lower or equal to the given level.

NOTE 1 The expanded measurement uncertainty is defined in ISO/IEC Guide 99:2007, definition 2.35.

NOTE 2 The coverage interval is defined in ISO/IEC Guide 99:2007, definition 2.36.

NOTE 3 Guidance on the role of measurement uncertainty in conformity assessment is given in ISO/IEC Guide 98-4.

This standard does not give requirements for the range of acceptable values of measurement uncertainty.

The expanded measurement uncertainty required for measurements can be indicated at the final engineering stage as requirements for optimization of management or electrical energy consumptions.

For the verification of compliance with standard requirements the measured values shall be compared to the specific road lighting installation parameters. Generally the requirement of EN 13201-2 shall be used.

For the verification of compliance with design expectation the measured values shall be compared to the congruent set of parameters specified and evaluated in the road lighting installation design.

If specific design parameters are given in the tender they shall be used.

In the declaration of compliance with standard requirements all the parameters that identify a given lighting class shall be mentioned. Non-conformities require the measurement of other photometric or not-photometric parameters in the installation, if the reasons of the discrepancies are to be investigated (see informative Annex E).

6 Measurement conditions

6.1 Ageing of lamps and luminaires before measurements

Generally measurements shall be carried out after a period of ageing of the light sources installed in luminaires of not less than the period specified, for a given lamp type, in EN 13032-1.

NOTE Guidance on the ageing period for LED luminaires is under consideration.

6.2 Stabilization after switch-on

Luminaires require a period of time for their light output to stabilize and all measurements shall be done after this stabilization period.

NOTE 1 Guidance on the stabilization period for different lamp typologies is given in EN 13032-1.

NOTE 2 Guidance on the stabilization period for LED luminaires is under consideration.

Monitoring readings shall be taken if there are concerns about the stability of the road lighting installation during the period of measurement.

EXAMPLE Illuminance measurements at the same location or locations should be taken at regular time intervals to ensure that stability has been reached and maintained before and during the period of definitive light measurements of the road lighting installation.

NOTE 3 Depending on the type of lamps and road lighting installation adequate information is obtained by monitoring the supply voltage.

6.3 Climatic conditions

6.3.1 General

The climatic conditions should be such as not to affect measures significantly, unless this is intended to.

NOTE In some weather conditions, atmospheric absorption significantly reduces the illuminance level or modifies the luminance measured.

If the climatic conditions at the measurement time do not represent the conditions required for the measurement aim, the person responsible for the measurement should decide whether to postpone the measurements.

6.3.2 Instruments

High or low temperatures may affect the calibration and the accuracy of the light measuring instruments.

Condensation or moisture on light transmitting surfaces of measuring instruments or on their electric circuits may affect their accuracy.

High wind speeds may make the measuring instruments vibrate or oscillate.

The influence of climatic conditions on the instrument performances shall be considered using correction factors. These uncertainties shall be considered in the measurement uncertainty evaluation.

If the climatic conditions are outside the range of the known correction factors the person responsible for the measurement shall postpone the measurements.

6.3.3 Road lighting installations

High or low temperatures or high wind speeds may affect the light output of thermally sensitive lamps or luminaires.

High wind speeds may make the luminaires oscillate.

The light transmission of the atmosphere will affect the light reaching the surface to be measured, and in the case of luminance measurements the light reaching the luminance meter from the surface to be measured.

The climatic conditions should be such as not to affect the measurements significantly, unless this is intended.

Luminance measurements shall only be performed when the road is dry when considering the M Classes requirements for dry conditions.

NOTE When taking dry surface measurements even a slight dampness of the road surface significantly affects the luminance of the road surface.

If the climatic conditions at the measurement time do not represent the conditions evaluated in the design phase of the road lighting installation, the person responsible for the measurement should decide whether to postpone the measurements.

6.4 Road conditions

The photometric characteristics of the road surface can largely evolve over time, especially during the first three years of age of the material.

In case of luminance measurements on a new road surface, measured values can be different from the expected ones because the actual reduced luminance coefficient is different from that used at the design stage (measured or obtained from standard road surface tables).

In this case road surface conditions can be estimated comparing illuminance measurements and illuminance calculation (see informative Annex E).

6.5 Extraneous light and obstruction of light

When measurements are intended to record the lighting performance of the road lighting installation only, direct or reflected light from the surrounds should be prevented or accounted for. Action taken to do this should be recorded on the test report.

NOTE 1 Light from the surrounds includes light from shop windows, advertising signs, road signals, lights on vehicles, other road lighting installations, sky glow, reflections from snow at the road side, etc. This lighting can sometimes be prevented, masked or switched off.

NOTE 2 A correction of the measured values can be made which is based on separate measurements taken with the road lighting installation switched off. A correction for sky glow depends on the cloudiness not being variable.

When measurements are intended to record the unobstructed light from the installation, if possible measurement areas should be selected which are free of obstructions that may produce shadows. These may include trees, parked cars, or road furniture. The presence of obstructions should be recorded in the test report.

Any shadow or interference from measurement systems or operators shall be reduced to the minimum possible. Care shall be taken that personnel making the measurements or equipment they are using does not obscure light that would otherwise reach the photometer head (illuminance measurement) or the measured road surface (luminance measurement) or reflect light that would otherwise not reach the photometer head or the measured road surface

When performing measurements during the lifetime of the installations, extraneous and obtrusive lights may be avoided or may be considered part of the global lighting performance in accordance with procedures described in the installation design, as part of a tender specification or pertinent standard.

7 Photometric measurements

7.1 Location of grid points

The nominal position of the grid points at which measurements are taken shall agree with those given in EN 13201-3.

If agreed with the tender, a reduced set of points, using at least 50 % of the standard grid points or an alternative grid can be adopted. This simplified grid or the alternative grid should have a significant distribution of points over the area used to define the full grid (see EN 13201-3).

The accuracy in the position of the measurements points shall be included in the measurement uncertainty evaluations.

When doing measurements during the lifetime of the road lighting installation, different measurement points may be taken with respect to the standard grid (see EN 13201-3). In this case a reduced or extended set of measurement points may be considered or suggested at the final engineering stage and accuracy evaluated following previously measured or design data. In some situations spot checks may be sufficient, however, the measurements shall consider the entire length of the road lighting installation and all its operating lighting classes.

7.2 Measurement of luminance

7.2.1 Location of observer (luminance meter)

For luminance measurement, the nominal positions of the observer shall agree with those given in EN 13201-3. The accuracy in the position of the observer shall be included in the measurement uncertainty evaluations.

Measurement can be carried out at a closer distance and at a proportional lower height so that the angle of view of the meter shall be at (89 ± 0,5)° to the normal to the road surface.

7.2.2 Selection of grid points

If some points of the grid are located on road markings (zebra, road crossing) they shall not be considered in the determination of the average luminance and the uniformity values. These points shall be recorded in the test report.

Some points of the grid can be located in the shade of an object (tree) or oil spread, etc. In such cases, it is recommended not to consider these points in the determination of the average luminance and the uniformity values and to recorder these points in the test report. Alternatively the appropriate particular parameters should be evaluated. The algorisms of the informative Annex B can be used.

The minimum and maximum values of the areas of framed surfaces at grid points shall be given in the test report.

7.2.3 Measurement of the average luminance

The average luminance is obtained as the average value of the luminances measured at the grind points (see 7.1 and 7.2.2) or by means of a single reading of the relevant area of the road surface.

For the measurement of average luminance by means of a single reading, the meter shall be an ILMD.

NOTE If a ILMD is not used, the luminance measurement gives, in effect, perspective weighting to each point and evaluates also the road surface between grid points.

7.2.4 Additional requirements for dynamic measurement systems

Dynamic luminance measurements shall be performed by the use of an ILMD.

Any effects on the luminance readings generated by the vehicle, such as shadows cast by the vehicle, light reflected from the vehicle to the luminance meter, inter-reflection shall be corrected, if possible, and shall be considered in the uncertainty evaluation.

The mobile vehicle shall not produce light or electronic noise that interferes with the instrument reading unless the instrument reading is corrected adequately and this correction considered in the uncertainty evaluation.

If the luminance detector is located inside the vehicle all the effects of the windscreen and of light inside the vehicle have in the luminance reading shall be evaluated and the measured values shall be corrected. This correction shall be considered in the uncertainty evaluation.

The mobile observer concept can be adopted. In this case the nominal angle of view of the meter shall be at 89° to the normal to the road surface and the measured grid points shall be in the transversal lines at the distance corresponding to the required angle of view with a tolerance of $\pm 2 \times D$, where D is the spacing between points in the longitudinal direction of the grid specified in EN 13201-3.

For measurements at the final testing phase, the maximum distance covered during the exposure time shall not be greater than 0,5 m and the accuracy in the definition of the nominal coordinates of the measurement points shall be better than D, where D is the spacing between points in the longitudinal direction of the grid specified in EN 13201-3.

For measurements during the lifetime of the installation, the maximum distance along which the sensors perform the measurements (during the acquisition time) shall not be greater than 2,0 m.

7.3 Measurement of illuminance

7.3.1 General

Any of four different type of illuminance shall be measured, depending on the lighting class or classes of the road lighting installation. These are:

— horizontal illuminance,

— hemispherical illuminance,

— semicylindrical illuminance,

— vertical illuminance.

7.3.2 Selection of grid points

Some points of the grid can be located in the shade of objects (i.e. trees). In such cases, it is recommended not to consider these points in the determination of the average and/or minimum illuminance and the uniformity values and to recorder these points in the test report. Alternatively, the appropriate particular parameters should be evaluated. The algorisms of the informative Annex B can be used.

7.3.3 Measurement of horizontal illuminance

For horizontal illuminance measurements the plane of the light sensitive surface of the photometer head shall be horizontal or parallel to the conventional road surface plane.

The nominal value of the height of the plane of the light sensitive surface of the photometer head (measurement height) shall be specified in the test report (see 7.3.7 and 7.3.8).

Theoretically the light sensitive surface of the photometer head should be positioned at ground level but generally this is not possible because of the detector thickness and any support e.g. gimbals.

NOTE 1 If the measurement height increases then discrepancies between the measured values and the real or calculated illuminance on the road surface increase too.

The influence of the measurement height shall be evaluated in the measurement uncertainty. If possible a correction factor for the measurement height should be determined. In this case the measurement uncertainty shall consider the corrected illuminance value and the influence of the correction factor uncertainty.

NOTE 2 A factor to correct for the measurement height is obtained by evaluating for every point of the used grid the ratio between the calculated illuminance on the road surface and the calculated illuminance on the plane at the nominal measurement height and parallel to the road surface.

7.3.4 Measurement of hemispherical illuminances

Hemispherical illuminance at a point can be measured by means of an illuminance meter for measuring planar illuminance by adopting the following procedure. The horizontal illuminance $E_{\mathrm{h,m}}$ from all the luminaires is measured at the point. The component $E_{\mathrm{l,m}}$ is measured from the *l*-th luminaire in turn by directing the surface of the photometer head so that it receives light at right-angles to its surface from this luminaire, and all other light is excluded. The measured hemispherical illuminance $E_{\mathrm{hs,m}}$ is given by:

$$E_{\mathrm{hs,m}} = \frac{1}{4}\left(E_{\mathrm{h,m}} + \sum_{l=1}^{n_{\mathrm{lu}}} E_{l,\mathrm{m}}\right) \quad (1)$$

where

$E_{\mathrm{h,m}}$ is the measured horizontal illuminance from all the luminaires of the road lighting installation;

$E_{\mathrm{l,m}}$ is the measured perpendicular illuminance from the *l*-th luminaire;

n_{lu} is the number of luminaire of the road lighting installation.

The other conditions for hemispherical illuminance are the same as the condition for horizontal illuminance.

7.3.5 Measurement of semicylindrical illuminances

The centre of the light sensitive surface of the photometer head shall be positioned nominally at 1,5 m above ground level. The light sensitive surface of the photometer head shall be vertical and have the correct orientation, typically facing longitudinally. Guidance is given in EN 13201-3.

7.3.6 Measurement of vertical illuminances

The centre of the light sensitive surface of the photometer head shall be positioned nominally at 1,5 m above ground level considering the grid points defined in EN 13201-3. The light sensitive surface of the photometer head shall be vertical and have the correct orientation, typically at right angles to the main directions of pedestrian movement. Guidance is given in EN 13201-3.

7.3.7 Additional requirements for static measurement systems

When illuminance is measured, to minimize interference from measurement systems or operators it is recommended that either an illuminance meter with photometer head attached to the meter by means of a cable or an illuminance meter with a remote hold cable shall be used. Cables shall be sufficiently long for observers to position themselves so that they do not obscure any of the light that would otherwise reach the photometer head.

The use of gimbals eases the task of maintaining the photometer head at the correct inclination, with respect to the conventional road surface plane.

For horizontal illuminance the measurement height shall be within 200 mm of ground level. If the road lighting system has luminaire at heights lower than 2 m the photometer head shall be within 50 mm of ground level or illuminance values shall be calculated also at the rated measuring height.

7.3.8 Additional requirements for dynamic measurement systems

In principle the mobile vehicle shall not shield lights that would otherwise reach the photometer head, unless these conditions are considered in the measurement procedures (as in split detector systems).

If the split detector method is adopted, the shield effect of the vehicle is considered in the measurement procedures. An estimation of the accuracy of the algorithm for obtaining the point illuminance from the front and read detector reading shall be considered in the uncertainty evaluation.

NOTE Guidance on design, use and metrological characterization of split detector systems is given in CIE 194:2011.

Any effects on the detector readings generated by the vehicle, such as shadows cast by the vehicle, light reflected from the vehicle, inter-reflection between the vehicle, the detector and its case, if present, shall be corrected and shall be considered in the uncertainty evaluation.

The mobile vehicle shall not produce light or electronic noise that interferes with the instrument reading unless the instrument reading is corrected adequately and this correction considered in the uncertainty evaluation.

If safety reasons justify it, the height of the photometric head shall be within 300 mm of ground level. If the road lighting system has luminaire at heights lower than 2 m illuminance values shall be calculated also at the rated measuring height.

For measurements at the final testing phase, the maximum distance along which the sensors perform the measurements (during the acquisition time) shall be no greater than 0,1 m.

For measurements during the lifetime of the installation, the maximum distance along which the sensors perform the measurements (during the acquisition time) shall not be greater than 1,0 m.

7.4 Measurement of Edge Illuminance Ratio (R_{EI})

The Edge Illuminance Ratio shall be measured following the requirements given for the measurement of horizontal illuminance and grids specified in EN 13201-3:2015, 8.6.

When the measured illuminance values in the grid points are known, the edge illuminance ratio is calculated using the following formulas derived from formulas specified in EN 13201-3:2015, 8.6, Formulae (42), (43) and (44):

$$R_{\mathrm{EI12,m}} = \frac{\overline{E}_{\mathrm{h,strip1,m}}}{\overline{E}_{\mathrm{h,strip2,m}}} \tag{2}$$

$$R_{\mathrm{EI43,m}} = \frac{\overline{E}_{\mathrm{h,strip4,m}}}{\overline{E}_{\mathrm{h,strip3,m}}} \tag{3}$$

$$R_{\mathrm{EI,m}} = \min(R_{\mathrm{EI12,m,}}, R_{\mathrm{EI43,m}}) \tag{4}$$

In some circumstances illuminance measurements in the zones outside the carriageway is difficult or impossible to obtain. In these situations the edge illuminance ratio cannot be measured but the ratios between the measured average horizontal illuminance and the calculated average horizontal illuminance of the same carriageway strips shall be given in the test report.

NOTE For example these zones are not accessible, not flat or with obstacles or shielding objects.

7.5 Measurement of the threshold increment (f_{TI})

If required the threshold increment can be measured with the following procedure.

If n_{lu} is the number of luminaires involved in the calculation of the threshold increment (see EN 13201-3:2015, 8.5), the threshold increment at the measurement instant is obtained considering the measured average road luminance, the measured illuminance produced by the l-th ($l = 1, \ldots, n_{lu}$) luminaire on a plane normal to the line of sight and at the height of the observer's eye, the angle between the line of sight and the centre of the l-th luminaire and using the algorithm of EN 13201-3:2015, 8.5, Formulae (35), (36), (37) and (38) here repeated with the obvious changes of symbols:

$$f_{\text{TI,m}} = 65 \cdot \frac{L_{\text{v,m}}}{\overline{L}_{\text{m}}^{0,8}} \tag{5}$$

$$L_{\text{v,m}} = \sum_{l=1}^{n_{\text{lu}}} L_{\text{v}l,\text{m}} \tag{6}$$

and

$$L_{\text{v}l,\text{m}} = 9{,}86 \left[1 + \left(\frac{A_{\text{y}}}{66{,}4} \right)^4 \right] \frac{E_{l,\text{m}}}{\theta_{l,\text{m}}^2} \quad \textit{if} \quad 1{,}0° < \theta_{l,\text{m}} < 60° \tag{7}$$

or

$$L_{\text{v}l,\text{m}} = E_{l,\text{m}} \left[\frac{10}{\theta_{l,\text{m}}^3} + \frac{5}{\theta_{l,\text{m}}^2} \left(\frac{A_y}{62{,}5} \right)^4 \right] \quad \textit{if} \quad 0{,}1° < \theta_{l,\text{m}} < 1{,}5° \tag{8}$$

where the same constraints of EN 13201-3:2015, 8.5 shall be considered and:

$\overline{L}_{\text{m}}$ is the average measured road luminance in candelas per square metre;

$L_{\text{v,m}}$ is the equivalent measured veiling luminance in candelas per square metre;

$L_{\text{vl,m}}$ is the equivalent measured veiling luminance of the l-th luminaire, in candelas per square metre;

l is the index of the pending luminaire in the summation;

n_{lu} is the number of luminaires of the road lighting installation that have an angle $\theta_{\text{l,m}}$ in the range specified in Formulae (7) or (8);

$E_{\text{l,m}}$ is the measured illuminance produced by the l-th luminaire on a plane normal to the line of sight and at the height of the observer's eye, in lux;

$\theta_{\text{l,m}}$ is the measured angle between the line of sight and the centre of the l-th luminaire, in degrees;

A_{y} is the age of the observer, in years.

During measurement at the final testing phase the observer positions shall be the same as those adopted for calculation. Only the position that gives the highest values of the threshold increment (worse situation) in calculation can be verified.

If an ILMD is used:

a) the illuminance produced by the *k*-th luminaire can be obtained considering the measured luminance of the luminaire and the angle $\theta_{k,m}$;

b) the $\theta_{k,m}$ angle can be obtained from a perspective analysis on the acquired image if the device allows it, or by the reference to the calculation process of EN 13201-3:2015.

The uncertainty of these parameters is strongly correlated to the optical properties of the ILMD (i.e. focal length of the lens, dimension of pixels of the detector array), of its optical and geometrical calibration and of the road lighting installation dimensions and layout. The focal length of the lens and the dimension of pixel of the detector array of the ILMD shall be given in the test report.

8 Measurement of non-photometric parameters

8.1 General

The selection of non-photometric measurements should be related to the purpose of the measurements (see 5.1).

It is strongly recommended where measurements are performed for comparison with requirement, detailed non-photometric measurements are required.

Where the measurements are required for monitoring the state of an installation then it is possible that less detailed non-photometric measurements will suffice

8.2 Supply voltage

When required, during the measurement the supply voltage shall be measured continuously or at least at the beginning of the measurement at a significant point in the electric installation, and observed.

NOTE 1 A recording voltmeter is preferable for this purpose.

NOTE 2 If the emitted luminous flux of the luminaires in the road lighting installation is considered stable when subject to variations of the supply voltage then the continuous measurement of supply voltage is not necessary.

8.3 Temperature and humidity

When required, the temperature and humidity shall be measured at a height of 1 m above ground level and recorded at least at the beginning of the measurements and eventually regularly along the measurement period.

8.4 Geometric data

If required, measurements shall be made of the geometry of the installation (see informative Annex E).

These may include measurements in plan of the installation, the height of the columns, and the length of the outreach. In addition tilt in application of the luminaires, orientation of the luminaires, and rotation of the luminaires shall be assessed if this data is relevant for meeting the aims of the measurement.

8.5 Instruments for non-photometric measurements

The measurement of non-photometric parameters that are relevant for the measurement aims shall be carried out with calibrated instruments.

The decision to use non-calibrated instruments for specific non-photometric parameters shall be reported in the test report. For these parameters measurement uncertainty shall not be evaluated.

NOTE Requirements for quality assurance of instruments may be requested as part of a tender or specification.

9 Test report

The test report should contain at least:

a) the objectives of the measurement;

b) all information gathered during the measurement if relevant for the aim of the measurement;

c) details of the instruments used, their number for an unambiguous identification and their calibration conditions (date, validity and metrological traceability);

d) details about the weather, environmental and electrical power supply conditions;

e) a reference or a short description of the procedures adopted for measurement and data elaboration, including the measurement uncertainty evaluation;

f) the measurement results with their measurement uncertainty;

g) the reason, justification and consequences of the selection of zones of the installation if it is not measured for its total length;

h) action taken to prevent or account for direct or reflected light from the surrounds;

i) all the other information mentioned in the previous clauses.

For dynamic system the average vehicle speed during the measurements shall be specified and the measurement uncertainty evaluation shall clearly indicate all the aspect correlated to movements and the correction factors eventually introduced.

The person responsible for the measurements shall sign the test report.

An example of test report is proposed in the informative Annex H.

Annex A
(informative)

Evaluation of tolerances in road lighting installation design

A.1 Tolerance analysis

A lighting project aims to guarantee a road lighting installation working in accordance with the required performance conditions (photometric quality parameters), considering any reasonable variation of key parameters that influence its performance.

The tolerance analysis is a mathematical tool for evaluating the influence in the expected performance values of the given road lighting installation of:

a) the tolerance in manufacturing of luminaires and light sources with reference to rated values (these tolerances are specified in product standard or are specified by manufactured);

b) the tolerance of the layout of road lighting installation and of the installation of the light source with reference to rated values specified by the design;

c) the measurement uncertainty of the road surface photometric characteristics (if luminance is considered).

NOTE The concept of manufacturing tolerance entails that the measurement uncertainty of parameters that characterized luminaires and light sources is lower than the manufacturing tolerance itself, because the measurement uncertainty is considered in specifying the tolerance interval of these products (see ISO/IEC Guide 98-4).

Tolerance analysis can be used during the design phase:

d) to reduce the installed energy used to the minimum level while meeting the required lighting performance parameters;

e) to reduce the installed luminous flux to the minimum level that guarantees the required level of performance, independently from the variability of the key parameters;

f) to understand the importance of a given key parameter in the depreciation of a photometric quality parameter compared to the design value;

g) to highlight the key parameters that should be controlled to minimize the risk of a road lighting installation not satisfying the design requirements;

h) to clearly specify road lighting installation constraints and requirements.

Using tolerance analysis the lighting designer can verify and/or state the probability that the installation will satisfy the required performance characteristics.

Tolerance analysis can also be used to evaluate reasons for discrepancies between measurement results and design expectations.

A.2 Parameters to be considered in the tolerance analysis

Tolerance analysis evaluates the sensitivity of nominal values of photometric quality parameters of a particular road lighting installation to the variation of the selected key parameters.

The main influencing parameters are indicated in Table A.1 Other parameters should be considered if known or if important for the layout of the road lighting installation or the type of luminaire adopted.

Table A.1 — Main influencing parameters for tolerance analysis

Influencing parameter	**Definition**	**Comment**	**Suggested probability distribution**	**Suggested value of tolerance**
Luminaire height (z coordinate)	Lighting column height tolerance (with bracket)	It can be due to tolerance in column installation but also to the column bend	Normal (Gaussian)	± 2,5 % height
Luminaire longitudinal position (x coordinate) spacing	Tolerance in the spacing between column		Rectangular	± 2 m
Luminaire transversal position (y coordinate)	Tolerance in transversal position of the luminaire		Normal (Gaussian)	± 0,2 m
Luminaire orientation	Tolerance in the orientation of the luminaire	It can be due to tolerance during the installation of or to the bending of the lighting column	Normal (Gaussian)	± 2°
Luminaire tilt	Tolerance in the tilt of the luminaire		Normal (Gaussian)	± 1°
Luminaire rotation	Tolerance in the rotation of the luminaire		Normal (Gaussian)	± 1°
Lamp luminous flux	Tolerance in luminous flux output of production lamps from nominal value.	Manufacture data or standard requirements	Rectangular	- 10 %
Luminaire luminous intensity distribution	Tolerance in the luminous intensity distribution of production luminaire from nominal value.	Manufacture data or luminaire test report. The variation can be due to manufacturing tolerances on luminaire, to the arc tube position, etc.	Rectangular	± 10 %
Supply voltage drop	Tolerance in the supply voltage of single luminaires	Variation due to supply voltage drop along the line for rated supply voltage	Rectangular	± 6 %
Road surface reflection data	Tolerance in Q_0 and r values	These tolerance should consider also the aging or only the measurement uncertainty	Normal (Gaussian)	± 5 % (if measured) ± 20 % (if standard table are used and no other information is available)

The influence of the supply voltage of the entire road lighting installation should be evaluated separately. The presence of a luminous flux controller can significantly reduce its influence.

A.3 Mathematical model for tolerance evaluations

The proposed mathematical model considers all the key parameters as uncorrelated.

If the luminous intensity distribution of the selected luminaire/luminaires is expressed in units of candelas per 1 000 lm of lamp flux (relative measurement) the manufacturer should give tolerance data of the luminaire referred to the nominal value of the installed lamp/lamps and the tolerance of the luminous flux of the lamp/lamps may be considered as an uncorrelated parameter.

If the luminous intensity distribution of the selected luminaire/luminaires is expressed in candelas (absolute measurement) the manufacturers should give tolerance data considering the tolerances of the installed lamp/lamps. Using these data the tolerance of the luminous flux of the lamp is not included in the tolerance analysis as a key parameter.

Tolerance analysis requires a list of all the key parameters together with the associated tolerance and the methods of evaluating the final uncertainty. For the sake of clarity, these data are presented in Table A.2.

Table A.2 — Tolerance analysis with uncorrelated input quantities

Input quantities						
Quantity	**Nominal value**	**Tolerance**	**Probability distribution**	**Sensitivity coefficient**	**Tolerance contribution**	
X_1	x_1	$u(x_1)$		c_1	$u_1(Y) = c_1\, u(X_1)$	
X_2	x_2	$u(x_2)$		c_2	$u_2(Y) = c_2\, u(X_2)$	
...	...	...		...	...	
X_i	x_i	$u(x_i)$		c_i	$u_i(Y) = c_i\, u(X_i)$	
...	...	...		...	...	
X_N	x_N	$u(x_N)$		c_N	$u_N(Y) = c_N\, u(X_N)$	
Output quantity						
Quantity	Nominal value				Combined uncertainty	Final uncertainty
Y	y				$u_c(y)$	U(95 %)
NOTE The symbols used in this table are described in A.4.						

A.4 Modelling the tolerance analysis

The calculated quantity Y depends on N key parameters through the functional relationship

$$Y = f(X_1, X_2, \ldots, X_i, \ldots, X_N) \tag{A.1}$$

where

Y is the calculated or output quantity (i.e. point luminance);

X_i is the i-th influence or input quantity.

For the input quantities X_i (i = 1,...,N) the following values are known or are supposed:

a) the nominal value x_i as a value of the input quantities X_i;

b) its tolerance, i.e. the range of possible values of x_i;

c) the probability distribution of x_i.

When a normal (Gaussian) probability distribution can be assumed for the quantity X_i then the tolerance $u(x_i)$ is the square root of the variance of the distribution.

When a rectangular probability distribution with upper limit $a_{i,\mathrm{u}}$ and lower limit $a_{i,\mathrm{l}}$ can be assumed then the nominal value is:

$$x_i = \frac{1}{2}\left(a_{i,\mathrm{u}} + a_{i,\mathrm{l}}\right) \quad \text{(A.2)}$$

and the tolerance is:

$$u(x_i) = \frac{a_{i,\mathrm{u}} - a_{i,\mathrm{l}}}{2\sqrt{3}} \quad \text{(A.3)}$$

The output quantity is completely specified by two values:

a) nominal value y;

b) its combine uncertainty $u_\mathrm{c}(y)$;

The nominal value y is:

$$y = f(x_1, x_2, \ldots, x_i, \ldots, x_N) \quad \text{(A.4)}$$

The combined uncertainty is:

$$u_\mathrm{c}^2(y) = \sum_{i=1}^{N} u_i^2(y) \quad \text{(A.5)}$$

Where the tolerance contribution u_i are:

$$u_i(y) = \left|c_i\right| u(x_i) \quad \text{(A.6)}$$

and the sensitivity coefficients

$$c_i = \frac{\partial f}{\partial x_i} = \frac{\partial f}{\partial X_i}\bigg|_{X_1 = x_1, X_2 = x_2, \ldots, X_N = x_N} \quad \text{(A.7)}$$

The sensitivity coefficients can be obtained numerically using algorithms of EN 13201-3 with small variation of X_i.

The result of a calculation is then expressed as:

$$Y = y \pm U \quad \text{(A.8)}$$

$$U = k \cdot u_\mathrm{c}(y) \quad \text{(A.9)}$$

where

U is the final tolerance;

k is called coverage factor.

Conventionally k = 2 is adopted in this standard

NOTE 1 Generally the combined tolerance is calculated numerically with:

$$Z_i = \frac{1}{2}\left[f(x_1, x_2, \ldots, x_i + u(x_i), \ldots, x_N) - f(x_1, x_2, \ldots, x_i - u(x_i), \ldots, x_N)\right] \quad \text{(A.10)}$$

and

$$u_i(y) = \left|Z_i\right| \quad \text{(A.11)}$$

$$c_i = \frac{Z_i}{u(x_i)} \quad \text{(A.12)}$$

NOTE 2 A generally adopted value of the level of confidence is p = 95 %

NOTE 3 The value of coverage factor k is chosen in accordance with the desired level of confidence p. Statistically the value of k = 2 gives a confidence level p = 95 % in conditions that are fulfilled in the majority of cases encountered in road lighting design.

Annex B
(informative)

Important particular parameters

B.1 General

For investigative purposes some normative photometric parameters may be evaluated on a longitudinal part of a lane instead of on the entire lane. Such information can be useful for understanding the reasons for reduced performance of a lighting system or the influence of screens (e.g. trees in a boulevard) or of light sources forming part of other public and private lighting systems.

B.2 Particular luminance and uniformity

Parameters of this type are evaluated on given points in a given longitudinal line *j* in specific measurement conditions *p*. They are:

a) the (particular) average luminance along a longitudinal line: $\overline{L}_{j,p}$;

b) the (particular) highest luminance along a longitudinal line $L_{\text{max,j,p}}$;

c) the (particular) lowest luminance along a longitudinal line $L_{\text{min,j,p}}$;

d) the (particular) overall linear uniformity of luminance along a longitudinal line $U_{\text{o,j,p}}(L)$;

e) the (particular) longitudinal uniformity of luminance along a longitudinal line $U_{\text{l,j,p}}(L)$.

Similarly, the same particular parameters for illuminance can be used.

B.3 Use of extended uniformity

The normative definitions of uniformities, both overall and longitudinal, require knowledge of the minimum and the maximum values of luminance or illuminance at a set of grid points.

These values can be strongly influenced by non-homogeneity of environment or of the road surface, such as oil spots, new pavement patches or shadows from objects, and uniformities evaluated in different zones of the same lane can differ significantly.

Uniformity obtained using average values on a given percentage of the total measured zone or line gives a more accurate description of the real situation than using the limit values at a single point.

To distinguish these particular uniformities and correlated parameters from the normative ones, the adjective "extended" is added to their name and the subscript "e(*c*)" is added at the end of their symbol.

The parameter "*c*" specifies the percentage of the total measured area of the surface, or the total length of the line used to average the photometric parameter.

Suggested values for *c* can be 10 %, 5 %, 1 % and 0,5 %. The appropriate choice should be made from experience and related to the particular situation.

NOTE 1 In presence of non-uniformities of the road surface (oil spreads, road dips, pavement road patches), of parked vehicles, trees, leaves or of lighting sources different from those of the road lighting installation, values of c = 10 % or c = 5 % are adequate.

NOTE 2 On motorways or other high-speed roads low values of c (extended results are similar to the normative values) are generally correct, while on main roads or streets in towns high values of c are adopted because they have a greater “filtering”effect. Generally, if $c \leq 0,3$ % the difference between extended and normative parameters is insignificant.

NOTE 3 The use of an ILMD for luminance measurements permits the measurement of the entire road surface and therefore allows the use of any value of c.

B.4 Evaluation of extended uniformities

To evaluate an extended parameter of quantity Q (luminance or illuminance) the measured zone or line is divided into G surfaces or segments, respectively of area or length A_g $(g = 1, ..., G)$ and for every surface a value $Q_{g,\mathrm{p}}(g = 1, ..., G)$ is measured. These values are then organized and renamed so that $Q_1 \leq Q_2 \leq ... \leq Q_g ... \leq Q_G$.

To evaluate the extended overall uniformities $U_{\mathrm{o},j,e(c)}(Q)$, the parameter B is chosen so that:

$$c = \frac{\sum_{g=1}^{B} A_g}{\sum_{g=1}^{G} A_g} \cdot 100 \quad (\%) \tag{B.1}$$

The extended overall uniformity $U_{\mathrm{o},p,e(c)}(Q)$ is obtained as the ratio between:

a) Q_a the weighted average value of Q in the first B surfaces or segments where Q has the lower values;

b) Q_b the weighted average value of in the entire measured zone:

$$U_{o,p,\mathrm{e}(c)}(Q) = \frac{Q_\mathrm{a}}{Q_\mathrm{b}} \tag{B.2}$$

where

$$Q_\mathrm{a} = \frac{\sum_{g=1}^{B} Q_{g,\mathrm{p}} A_g}{\sum_{g=1}^{B} A_g} \tag{B.3}$$

$$Q_\mathrm{b} = \frac{\sum_{g=1}^{G} Q_{g,\mathrm{p}} A_g}{\sum_{g=1}^{G} A_g} \tag{B.4}$$

When Q is illuminance or luminance and the measurement is carried out using the moving observer technique the area of the surfaces or the length of the segments can be considered equal to each other and the formulae become:

$$c = \frac{B \cdot A_g}{G \cdot A_g} \cdot 100 = \frac{B}{G} \cdot 100 \quad (\%) \tag{B.5}$$

and

$$Q_{\mathrm{a}} = \frac{1}{B} \sum_{g=1}^{B} Q_{g,\mathrm{p}} \tag{B.6}$$

$$Q_{\mathrm{b}} = \frac{1}{G} \sum_{g=1}^{G} Q_{g,\mathrm{p}} \tag{B.7}$$

The same formulae are true for the extended overall uniformities along a longitudinal line $U_{\mathrm{o,j,p,e}(c)}(Q)$.

To evaluate the extended longitudinal uniformities $U_{\mathrm{l},j,\mathrm{p,e}(c)}(Q)$, the parameters B and M are chosen so that:

$$\begin{cases} c = \dfrac{\sum_{g=1}^{B} A_g}{\sum_{g=1}^{G} A_g} \cdot 100 \quad (\%) \\ \\ c = \dfrac{\sum_{g=M}^{G} A_g}{\sum_{g=1}^{G} A_g} \cdot 100 \quad (\%) \end{cases} \tag{B.8}$$

The extended longitudinal uniformity $U_{\mathrm{l},j,\mathrm{p,e}(c)}(Q)$ is obtained as the ratio between:

a) Q_{a} the weighted average value of Q in the first B surfaces or segments where Q has the lower values;

b) Q_{c} the weighted average value of Q in the last (G-M) surfaces or segments where the Q has the higher values:

$$U_{\mathrm{l},j,\mathrm{p,e}(c)}(Q) = \frac{Q_{\mathrm{a}}}{Q_{\mathrm{c}}} \tag{B.9}$$

where

$$Q_{\mathrm{c}} = \frac{\sum_{g=M}^{G} Q_{g,\mathrm{p}} A_g}{\sum_{g=M}^{G} A_g} \tag{B.10}$$

NOTE Also the maximum, minimum and average illuminance or luminance can be defined as extended parameters. The above formula of the parameter Q can be used.

Annex C
(normative)

Conventions for symbols of photometric quality parameters

The symbol of a parameter consists of one letter (e.g. L, E, E_{min}, E_{max}) and eventually one or more subscripts separated by commas may be used. The first subscript x, if needed, specifies the meaning of the parameter:

— r for requirement based on lighting classes (EN 13201-2);

— d for values effectively required by the road authority (design expectations);

— c for calculated values;

— m for measured values.

The following subscript, if present, specifies the geometric conditions (e.g. along a line in a lane, etc.); and the last subscript specifies the measurement conditions (subscript p in 3.7) and, if necessary, the evaluation condition (see informative Annex B).

NOTE The normative parameters have no subscripts for measurement and evaluation conditions.

If the parameter evaluates measurements along a line and if needed to avoid confusion, the line is specified by adding a subscript to the parameter symbol, such as “l1”, “l2”, etc. Letters or numbers can be used for this subscript, but the convention used shall be made clear in the test report.

Generally the particular parameters need the measurement conditions to be clearly specified. The following convention shall be adopted for the subscript:

a) if the photometric quantity is integrated along a segment or in a condition that can be approximated in this way the subscript is letter “s” and the length of segment shall be specified with the photometric value;

b) if the photometric quantity is integrated over an area that cannot be considered differential the subscript is letter “a” and the area value shall be specified with the photometric value.

When static measurements are carried out the acceptance area of illuminance meter is considered to be a point.

When measurements are carried out using a dynamic measurement system one dimension of the integrated area can be very small with respect to the other dimensions. In these situations finite surfaces can be considered to be segments.

Knowledge of the effective dimensions of the segment or area measured is important when measurements are compared, or when corrections are made to obtain a normative parameter from a measured one. For this reason such information shall be given in the measurement report and, if necessary to avoid ambiguity, made clear in the symbol of the particular parameter.

EXAMPLE The symbol of the normative lowest luminance measured along the centre line is $L_{min,m,c}$ and its value is obtained as the lowest value in the set of (normative) luminance values L_m measured at N points on the longitudinal line along the centre of a given driving lane, as specified by EN 13201-3 and following the requirement of this standard. The symbol of the particular lowest luminance measured along the centre line is $L_{min,m,c,p}$ and its value is obtained as the lowest value in the set of particular luminance values $L_{m,p}$ obtained at N' given points on the longitudinal line along the centre of a given driving lane.

The meaning of p (number of points, geometrical measurement conditions, etc.) shall be described in the context where the symbol is used.

Annex D
(normative)

Guidelines for measurement systems for adaptive road lighting

For measurement systems used in adaptive road lighting to control the lighting output of luminaires the following requirements should be considered in addition or as a modification of the general part.

Measurement requirements need meticulous choice of the measured parameters (luminance or illuminance) conditions and evaluation of measurement procedures and instrument characteristics to obtain the required accuracies. The use of particular parameters may simplify the measurement system and reduce its cost without compromising the measurement aims. The measurement uncertainty of the controlling system and of the set measurement should be considered in order to be sure to guarantee the maintained value of the photometric quality parameters as required in EN 13201-2.

Difficulties in adequately measures the illuminance near the road surfaces (position of the sensor, strong influence of stray light from light sources different from those of the road lighting installations, dusts on the detector surface, etc.) suggest to measure the road luminance, at a specified angle, also when the standard lighting requirement is given as average illuminance value

The controlling parameters should be measured within the time constraints specified in the design or pertinent standards requirements.

Other photometric or non-photometric parameters may be measured for monitoring or to increase the accuracy and reliability of the controlling system.

No measured photometric quality parameters may be obtained from previous periodic measurements, from the final testing/commissioning measurement or from set measurement.

Strategies to avoid unwanted operating conditions of the road lighting installation when the measurement conditions can give wrong results should be adopted. These conditions include:

a) during the stabilization period the luminous flux control should be suppressed or applied following specific design requirements or pertinent standard. The stabilization period is determined considering guidance given in EN 13032-1;

b) climatic conditions that do not represent the conditions required by design and management of the road lighting installation;

c) the detector working conditions (temperature, humidity, condensation or moisture on light transmitting surfaces) are outside its operating range.

Extraneous and obtrusive lights may not be avoided during measurements. During the set measurement the influence of extraneous and obtrusive lights may be evaluated. Strategies for their management should be considered in the installation design or from pertinent standards.

If luminance is measured:

a) the luminance meter position may be different from the observer position required in EN 13201-3;

b) different measurement point/points of the grid described in EN 13201-3 may be adopted;

c) luminance meters with a narrower measurement cone can be used at a greater distance and at a proportionally greater height so that the angle of view of the meter should be at (89 ± 0,5)° to the normal to the road surface;

d) other angle of view may be adopted if during the set measurement a correlation factor between the measured luminance and the luminance in normative conditions is evaluated;

e) the constraints on field of view of the luminance meter may be relaxed, if only the road surface is framed and the correlation between the measured luminance and the luminance in normative conditions can be established.

If necessary during the set measurement a correction factor can be measured or calculated to estimate the normative luminance value.

The set measurement should be carried out after a period of aging not less than the period specified, for a given lamp type, in EN 13032-1.

If this is not possible, the set measurement and samples of the controlling signal should be acquired at the same moment.

Absolute calibration of the luminance and illuminance meter can be omitted if the control method guarantees the traceability of the controlled parameter for example using the set measurement, which gives a sort of calibration factor.

If to measure the quantity used to control the lighting output of luminaires, calibrated instruments in geometrical conditions similar to the normative ones are used, the set measurement can be omitted.

Consideration should be given to the long term ageing of the instrument and influence of environment conditions.

The presence of rain or snow may modify not only the instrument performances and therefore its reading but also the above mentioned calibration factor. Strategies to avoid unwanted operating conditions of the road lighting installation should consider also these aspects.

Annex E
(informative)

Measurements for investigation of discrepancies between photometric measures and design expectation

Measurements carried out as and when required to investigate discrepancies between measured results and design expectations or to understand environment influence require additional requirements or considerations.

All the parameters necessary to understand discrepancies should be measured.

This may include geometrical parameters of the installation like height of the columns, tilt, orientation and rotation in application of the luminaires, type and model of luminaires and lamps, detailed electrical conditions (i.e. supply voltage at as many lighting columns as necessary) and the road surface photometric properties.

The influence of extraneous and obtrusive lights should be a part of the investigations.

New or different zones of the road lighting installation can be measured to obtain a deeper knowledge of the real situation.

For roads adopting M lighting classes, the measurement of the photometric characteristics of the road surface can be part of the investigation process. In such cases, the comparison of illuminance measurements and illuminance calculation with the required luminance values estimates the road surface conditions and gives enough information to justify discrepancies.

If necessary, for roads in a dry condition, a number of samples of the road surface should be removed for measurement under laboratory conditions or the road surface characteristics can be measured in the field with suitable instrumentations and methods able to guarantee adequate measurement uncertainty for the investigation aims.

NOTE Guidance on measurement of road surface characteristics is given in CIE 66:1984 and CIE 144:2001.

Annex F
(informative)

Measurement uncertainty evaluation[1)]

F.1 Luminance measurements

F.1.1 Sources of uncertainty

The main uncertainty parameters of measuring instruments and measurement procedure to be considered are summarized in Table F.1 and in Table F.2 respectively.

For measurement at the final testing phase the instability of the road lighting installation should be considered in the uncertainty evaluation.

The installation short-term instability contribution in the measurement uncertainty can be obtained from several measurements of luminance at the same point.

Table F.1 and Table F.2 are not exhaustive and do not propose any grading of the relevance of different parameters. The aim is to show the importance of a genuine analysis of the metrological characteristics of the measurement system, and the need for a real understanding of the degree of influence of all the parameters that influence the outcome. It will be necessary for the person responsible for the measurements to use knowledge and experience to identify the potential for improving measurement system performance if need, and/or to identify the less important parameters that should be mentioned but need not be accurately evaluated.

It can be difficult to evaluate separately the influence of the parameters given in Table F.2. In this case the total influence of these parameters may be evaluated as a single contribution to measurement uncertainty.

Table F.1 — Parameters that influence the uncertainty of luminance measurement and that are correlated to the measuring instruments

Instrument	Parameter	Notes
Photo detector	Calibration	From the calibration certificate (see U_{cal} in EN 13032-1)
	Spectral responsivity	To weigh the influence of the difference between the calibration source spectrum (e.g. illuminant A) and the real measured spectra (see f_1' in EN 13032-1) In the spectra of the road reflected light is measured a correction factor can be applied and only the uncertainty of this correction shall be considered
	Directional response	If a traditional luminance meter is sued see f_2' in EN 13032-1. If a ILMD is used, to weight the lens and shutter influence on the detector responsivity, pixel by pixel considering the direction of the grid points.[a]
	Linearity	Signal linearity from the calibration certificate or by ad hoc measurement (see f_3 in EN 13032-1)

1) Detailed information on the theory of measurement uncertainty are in ISO/IEC Guide 98, ISO/IEC Guide 99 and CIE 198-2011.

Instrument	Parameter	Notes
	Display resolution	See f_4 in EN 13032-1 If an ILMD is used the effective analogue to digital A/D converter resolution of the instrument electronics shall be considered
	Pixel saturation in the framed field	If an ILMD is used the influence in the measured zone of the saturation of pixels outside this zone
	Framed luminous sources in the field	The influence in the measured zone of light sources in the surrounding field that the instrument frames (see $f_{2,u}$ in EN 13032-1)
	Not framed luminous sources in the field	The influence in the measured zone of light sources the instrument does not frame, but that are present in the environments
	Noise and dark frame	The influence of the detector noise and dark current values and repeatability if a ILMD is used, the values are obtain pixel by pixel from dark frames
	Focusing	The influence of being out of focus if the measured zone is not at the right distance (see f_{12} in EN 13032-1)
	Influence of non-uniform illumination of the acceptance areas of the framed zone	The construction of some photometer heads lead to a significant dependence of the responsivity (including the relative spectral responsivity) on the incident-light position in the acceptance area (see f_9 in EN 13032-1). If an ILMD is used, only the detector surface were the measuring zone is framed shall be considered.
	Other parameters defined in EN 13032-1	The influence of the other performance parameters specified in EN 13032-1 as a whole or parameter by parameter
[a] Guidance on the characterization of ILMD is under consideration.		

Table F.2 — Parameters that influence the uncertainty of luminance measurement and that are correlated to the measurement procedure

Measurement procedure		
Parameter	**Description**	**Notes**
Point identification	Influence of the uncertainty in the point coordinates	If road markers are used, accuracy of alignment and positions of the markers
	Influence of the perspective correction algorithm	If a perspective correction algorithm is used, accuracy of the calculated measurement point coordinates derived from the accuracy of the road reference point and of the perspective correction algorithm
Measurement area	Influence of the effective area of the point of measurement	Dimension of the framed surface used to acquire the point of luminance
Real position	Influence of the real camera position compared to the nominal position	Influence of tolerances respect to the nominal position required in this standard or Influence of the different detector position.

F.1.2 Additional uncertainty sources for dynamic systems

Many sources of uncertainty are more critical in dynamic measurement systems than in static ones and some sources are typical of dynamic systems.

The vehicle speed is an important factor. The use of particular parameters (see 3.5) is suggested to better describe the measured quantities.

If only one transit is done, only one measure for point is possible. If required, the installation short-term instability, should be obtained or estimated from ad hoc measurements carried out in a zone of the installation for a period of time at least equal to the time spends for the dynamic measurement of the same installation.

A non-exhaustive description of particular uncertainty sources is in Table F.3 for parameter correlated to measuring instruments and in Table F.4 for parameter correlated to measurement procedure. These tables shall be read as an addendum of Table F.1 and of Table F.2 respectively.

Table F.3 — Additional parameters of Table F.1 that influence the uncertainty of luminance measurement carried out with dynamic systems

Instrument	Parameter	Notes
Photo detector	Influence of movement	The measured area is longer for the movement of the vehicle. For example at 90 km/h and with exposure time of 20 ms the space is 0,5 m

Table F.4 — Additional parameters of Table F.2 that influence the uncertainty of luminance measurement carried out with dynamic systems

Parameter	Description	Notes
Point identification	Influence of the uncertainty in the point coordinates	Accuracy in defining the position of the dynamic system detector/detectors with respect to the initial reference point and thereafter the measurement points with respect to the installation
Measurement area	Influence of the effective area of the point of measurement	Dimension of the framed surface used to acquire the point of luminance shall consider the vehicle movement
Real position	Influence of the real camera position compared to the nominal position	Influence of tolerances with respect to the nominal position required in this standard. Both longitudinal and transverse positions are important. Detector tilting affects the measurement distance

F.1.3 Evaluation of point luminance uncertainty

In this example the uncertainty of the measurement system is considered, and not that of the influence of the road lighting installation, measurement point position and weather.

In the proposed model of the measurement procedure the dark image reading, the influence of sources within and outside the frame and ghost images are subtracted from the detector reading. The result shall be multiplied by the calibration coefficient and by other correction factors correlated to parameters described in CIE S 023/E:2013. Their value is usually unity.

The point measured luminance L_m is:

$$L_\mathrm{m} = (R_\mathrm{m} - R_\mathrm{d} - R_\mathrm{i} - R_\mathrm{o} - R_\mathrm{g}) K_\mathrm{cal} K_{\mathrm{f}_1} \cdot K_{\mathrm{f}_2} K_{\mathrm{f}_3} K_{\mathrm{f}_4} K_{\mathrm{f}_{12}} K_{\mathrm{f}_\mathrm{cie}} \qquad \text{(F.1)}$$

where

R_m is the detector reading (measure image);

R_d is the detector reading (dark image);

R_i is the signal due to luminous sources inside the frame;

R_o is the signal due to luminous sources outside the frame;

R_g is the signal due to ghost images;

K_{cal} is the detector calibration;

$K_{f_1'}$ is the detector V(λ) match;

K_{f_2} is the detector directional responsivity;

K_{f_3} is the detector linearity;

K_{f_4} is the detector A/D real resolution;

$K_{f_{12}}$ is the influence of focusing distance;

$K_{f_{cie}}$ is the influence of other, generally less important performance parameters described in CIE S 023/E:2013.

NOTE 1 In well-designed measurement system R_i, R_o, and R_g are usually negligible, compared to R_m and R_d therefore only their uncertainty is important.

NOTE 2 In dynamic measurement systems only one measurement is carried out so the standard uncertainty of R_m is equal to the repeatability of the luminance meter.

NOTE 3 Usually in ILMD all the parameter of the proposed model (Formula F.1) are different from pixel to pixel.

F.2 Illuminance measurements

F.2.1 Sources of uncertainty

The main uncertainty parameters of measuring instruments and measurement procedure to be considered are summarized in Table F.5 and in Table F.6 respectively.

For measurement at the final testing phase the instability of the road lighting installation shall be considered in the uncertainty evaluation.

The installation short-term instability contribution in the measurement uncertainty can be obtained from several measurements of illuminance at the same point.

Table F.5 and Table F.6 are not exhaustive and dos not propose any grading of the relevance of a different parameter. The aim is to show the importance of a genuine analysis of the metrological characteristics of the measurement system and of the need for a real understanding of the degree of influence of all the parameters that influence the outcome. It will be necessary for the person responsible for the measurements to use knowledge and experience to identify the potential for improving the measurement system performance if needed and/or to identify the less important parameters that should be mentioned but need not be accurately evaluated.

It can be difficult to evaluate separately the influence of the parameters given in Table F.6 under the set "Measurement procedure". In this case the total influence of these parameters may be evaluated as a single contribution to measurement uncertainty.

Table F.5 — Parameters that influence the uncertainty of illuminance measurement and that are correlated to the measuring instruments

Instrument	Parameter	Notes
Photo detector	Calibration	From the calibration certificate (see U_{cal} in EN 13032-1)
	Spectral responsivity	To weigh the influence of the difference between the calibration source spectrum (e.g. illuminant A) and the real measured spectra (see f_1' in EN 13032-1) If the spectra of the incident light is measured a correction factor can be applied and only the uncertainty of this correction shall be considered.
	Directional responsivity	To weight the influence directional responsivity see f_2 in CEN/TR 13201-1
	Linearity	Linearity in the measured range can be found in the calibration certificate or can be estimated by ad hoc measurement (see f_3 in EN 13032-1)
	Display resolution	See f_4 in EN 13032-1
	Change of scale	See f_{11} in EN 13032-1
	Noise and dark current	The influence of detector noise and dark current values and repeatability
	Other parameter defined in EN 13032-1	The influence of the other performance parameters specified in EN 13032-1 as a whole or parameter by parameter

Table F.6 — Parameters that influence the uncertainty of illuminance measurement and that are correlated to the measurement procedure

Parameter	Description	Notes
Point identification	Influence of the uncertainty in the point coordinates	If road markers are used, accuracy of alignment and positions of markers
Measurement area	Influence of the effective area of the point of measurement	This term can be neglected for most detectors in general use
Real position	Influence of the real detector position compared to the nominal position	See point identification and detector real position and tilt condition compared to nominal condition

F.2.2 Additional uncertainty sources for dynamic systems

Many source of uncertainty are more critical in dynamic measurement systems than in static ones. For example in split detector systems, the actual directional sensitivity shall be obtained considering tolerances in the position of the two detectors and of their tilt.

Also the vehicle speed is important because it can increase the above mentioned tolerances and measured area (see the introduction of particular parameters in 3.5).

If only one transit is done, only one measure for point is possible. If required, the installation short-term instability, should be obtained or estimated from ad hoc measurements carried out in a zone of the installation for a period of time at least equal to the time spends for the dynamic measurement of the same installation.

A non-exhaustive description of peculiar uncertainty sources is in Table F.7 for parameter correlated to measuring instruments and in Table F.8 for parameter correlated to measurement procedure. These tables shall be read as an addendum of Table F.5 and of Table F6 respectively

Table F.7— Additional parameters of Table F.5 that influence the uncertainty of illuminance measurement carried out with dynamic systems

Measuring instruments		
Instrument	**Parameter**	**Notes**
Photo detector	Directional responsivity	To weigh the influence of the detector shields. In split detector system two readings are summed when the two detectors are in the same nominal position
	Linearity	In the range of measured values. The measuring range can be different from the minimum and maximum road illuminance because singe hemisphere are considered. The measuring scale cannot be the best one because it can be known only after measurement
	Change of scale	To avoid out of range conditions a predictive change of amplifier gain can be adopted

Table F.8— Additional parameters of Table F.6 that influence the uncertainty of illuminance measurement carried out with dynamic systems

Measurement procedure		
Parameter	**Description**	**Notes**
Point identification	Influence of the uncertainty in the point coordinates	Accuracy in defining the detector positions considering the three special coordinates. According to the system characteristics the uncertainty of the longitudinal coordinate can increase with the measuring distance.
Measurement area	Influence the effective area of the point of measurement	Vehicle speed and sampling period
Total illuminance	Influence of the real detector position compared to the nominal position	The signal of the two detectors are not acquired at the same point
Real position	The three parameters of Table F.6	These parameters can be evaluated as a single contribution to measurement uncertainty. In split detector system, the tilt angle and the three special coordinate during the sampling time shall be considered for the front and rear detectors and discrepancies between the two resolved when the total illuminance is evaluated. Usually the horizontal illuminance is measured with the detector parallel to the road surface

F.2.3 Evaluation of point illuminance uncertainty

The evaluation of uncertainties can be simplified using a model similar to that described for luminance measurements (see F.1.3). For illuminance, the uncertainty in the detector position plays an important role in increasing the expanded uncertainty and shall be evaluated when considering the light distribution on the road surface.

Annex G
(informative)

Practical information

G.1 General

This annex gives practical information that is useful for preparing measurement procedures.

The example given should be adapted where not all parts are relevant.

G.2 Measurement precautions

The following is a non-exhaustive list of precautions that should be considered to avoid wrong measurement or inaccuracies:

— check position and orientation of the instrument;

— spectral sensitivity adequately corrected for the type of lamp used (i.e. LED);

— possible instrument damage during manipulation and transport;

— preliminary testing of instrument before starting the measurement procedure;

— calibration certificate not expired;

— battery in good condition;

— instrument warm-up in accordance with manufacture instructions;

— dark current compensation or auto calibration;

— correct choice of instrument range.

G.3 Measurement organization

The use of check lists facilitate the organization of the measurement campaign and avoid the oversight of important steps or precautions especially when the measurement activity is carried out in hard conditions.

For luminance measurement, in advance of taking measurements, it can be convenient to mark out the relevant grid on the road surface with markers which allow the meter to be correctly aligned, for example when they are viewed through the viewfinder of the luminance meter. If they appear in the measuring cone of the luminance meter they should be removed before a measurement is taken.

Annex H
(informative)

Example of report

H.1 Premise

This is an example for given guidelines in the organization of a report without any requirements or constrains.

The parameters included in the test report should be considered with reference to requirements in Clause 9.

H.2 General test information

Name of site	
Objective of measurement	
Type(s) of measurements	
Date of test	
Time of test	Beginning
	End
Names of personnel participating in test	

H.3 Geometrical data

Sketch of the road, and relevant surroundings, with dimensions and positions of the luminaires, and the position of road furniture, parked vehicles, and any other obstructions.

H.4 Road surface data

Type of road surface	
Age of road surface	
Observations on condition of the road surface	

H.5 Lamp and luminaire data

Luminaire of type 1	Identification	
	I-table reference	
	Tilt (degrees)	
	Mounting height (m)	
	Age	
	Position respect to the reference system	
	Other data	
Light sources in luminaire of type 1	Type	
	Power (W)	
	Age	
	Number of light sources in the luminaire	
	Ballast	
	Dimming method	
Luminaire of type 2	Identification	
	I-table reference	
	Tilt (degrees)	
	Mounting height (m)	
	Age	
	Mounting method	
	Other data	
Light sources in luminaire of type 2	Type	
	Power (W)	
	Age	
	Number of light sources in the luminaire	
	Ballast	
	Dimming method	

H.6 Electricity supply

Average supply voltage during measuring period (V)	
Lowest supply voltage during measuring period (V)	

H.7 Environmental conditions

Environmental conditions	Beginning	End
Weather and Visibility		
Temperature °C		
Humidity		
Road surface appearance (wet, dry or damp)		

H.8 Condition of installation

Geometry of installation	
Tilt in application of luminaires	
State of maintenance of luminaires	
Extraneous light	
Obstruction to light	
Other aspects of installation	

H.9 Measuring devices data

Meter type	Manufacture	Model	Instrument number	Date of calibration	Name of certifying authority
Horizontal illuminance					
Hemispherical illuminance					
Semicylindrical illuminance					
Luminance Angular size of measuring field (°) Vertical: Transverse:					
Luminance Height of photometer head (m)					
Voltmeter					

H.10 Photometric measuring devices characteristics

Meter type	Characteristic	Value
Horizontal illuminance	Nominal height of photometer head (m)	
Hemispherical illuminance	Nominal height of photometer head (m)	
Semicylindrical illuminance	Nominal height of photometer head (m)	
Luminance	Angular size of measuring field (°)	
	Vertical	
	Transverse	
	Nominal height of photometer head (m)	

H.11 Measurement grid

Indicate on the diagram:

— the positions of the luminaires,

— the measurement points,

— the photometric values and their uncertainty,

— the operative direction or directions for semicyclindrical and vertical illuminance,

— for luminance: position of photometer head relative to grid.

H.12 Light monitoring record

Switching on time of installation		
Time at commencement of measurements		
Location 1	Average illuminance during measurement time	
	Standard deviation of illuminance during measurement time	
Location 2	Average illuminance during measurement time	
	Standard deviation of illuminance during measurement time	
Location 3	Average illuminance during measurement time	

H.13 Specific information for dynamic measurements

Luminance measurements	Method of measurement, for example by recording images for laboratory analysis or by point measurement by luminance meter	
	Precautions to allow for transmission loss by windscreen, if present	
Illuminance measurements	Method of measurement including method of allowing for vehicle shadow	
Illuminance and luminance measurements	Method of linking geometrical position of recording instrument to positions of measurement points	
	Uncertainty in linking geometrical position of recording instrument to positions of measurement points	
	Uncertainty of recorded values	
	Indication of how quality characteristics are calculated	

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