# Metrology of Road Surface for Smart Lighting

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***Abstract*—The knowledge of the luminance coefficient *q* or of the reduced luminance coefficient *r* of road surface is an unavoidable requirement for designing road lighting installations able to assure adequate road luminance for visual conditions, energy consumption and traffic safety according to standard requirements. Unfortunately *q* available data refers to measurements made during the seventies with no traceability or measurement uncertainty. In the last 40 years the road surfaces pavements evolved as well the road lighting sources and luminaires. EMPIR project SURFACE will provide validated, optimised and reliable geometrical conditions for the measurement of *q* as well as reference data representative of current road pavements and future needs, as support of the European Standardisation process, CIE and European Metrology infrastructure.**

***Index Terms*--EMPIR SURFACE project, EURAMET, Road lighting design, Road luminance coefficient, Smart lighting**

## I. INTRODUCTION

Reference Standard for road lighting (EN 13201 series [1], [2], [3], [4]) considers for motorize traffic the road luminance level the key parameter to obtain adequate vision conditions and traffic safety: the road luminance is

directly related to the direction of the incident luminous flux, the direction of view and the reflection characteristics of the road surfaces.

For motorized traffic EN 13201-2 [1] specifies, for the assigned road class, requirements for the average road surface luminance, the overall uniformity of the luminance, the longitudinal uniformity of the luminance, the threshold increment and the edge illumination ratio. The design of every road lighting system is based to ensure compliance with the aforesaid values, and is calculated (i.e. luminous flux installed and luminaires spacing) following [2] and using the reference value of the *luminance coefficient (q)* as tabulated in reference tables for the selected road surface. Unfortunately, reference tables in the standard don't specify values, but only the geometries (lighting and viewing angles) to which the *q* values should be known. The only published reference data are in a CIE reference document [5] and are older than 40 years and without information on measurement uncertainty.

This means that current road lighting systems have been designed using data of road photometric characteristic not representative of effective road surfaces: in the last 40 years both road surfaces and luminaires evolved as well the awareness of uncertainty and its relationship with industrial tolerances. Some studies show that the current available CIE data [5] can lead to errors on average luminance often over 30% and sometimes over 50% [6]. Solid-state sources (SSL) have sharp luminous intensity distribution; this simplifies the energy consumption optimization but increase the influence of the road surface characteristic in reflection, especially when the luminance uniformities are considered. Moreover SSL brings the opportunity of smart lighting systems, i.e. systems or luminaires able to adapt their luminous flux end/or luminous intensity distribution at any time, according to the brightness and specularity of the road pavement. In these systems to stabilize the road surface luminance, the road pavement is usually framed by a control Image Luminance Measuring Device (ILMD) under different geometrical condition than reference standard geometries. The ILMD calibration is made according to several simplifications on the road surface reflectance behaviour or with on-site procedures [3]. Also the spectral radiant coefficient shall be considered with a specific care in the mesopic concept [7], which has been introduced in some national standards (UNI, BSI) and international guidelines [8].

The knowledge of the road surface luminance coefficient is important in the optimization of the energy performances (EN13201-3 [2] and EN 13201-5 [4]) of the lighting installation, but also in glare evaluation [2] and in the improvement of safety, comfort during night and energy savings trough LED adaptive lighting (infrastructure toward smart cities). The luminance coefficient and/or the reduced luminance coefficient (are the required and unfortunately missed parameters.

Unfortunately EU Standard Organization (CEN) isn't able to provide the necessary data and research, so a specific pre-normative call was launched under the 2016 calls of the European Metrology Programme for Innovation and Research (EMPIR), that is a metrology focused program of coordinated Research & Development funded by European Commission and participating countries within the European Association of National Metrology Institutes (EURAMET). A Joint Research Project (JRP) SURFACE "Pavement surface characterisation for smart and efficient road lighting", dealing with road surface photometry, was submitted and subsequently funded for developing metrology research to support road lighting standardisation.

This project is lead by the National Metrological Institute (NMI) of Italy (INRIM) and includes NMI of Estonia, France, Finland, Sweden and Switzerland, plus a National French Research Centre (Cerema) and two industrial companies (Zehntner, measuring instruments and Optis, software simulation), with the support of CEN, CIE and National Standardisation Organisation, road Authorities as well a group of Stakeholder.

## II. SUMMARY OF THE PROJECT

### *A. Scientific objectives*

The project wants to solve the European standard lacks in road surface photometry:

- providing reference data of current road surfaces, and new reference geometrical condition for reference data useful for needs of smart and LED lighting and for the reduction of the environmental impact (obtrusive light and light pollution) of road lighting installations;
- establishing traceability through an intercomparison open to stakeholder and EU laboratories;
- providing guidelines on metrological specification for instruments, characterisation methods and uncertainty evaluation for road surface photometry, for current and future needs of EU normative;
- making available to EU market a software for uncertainty calculation and Certified Reference Materials for instrument calibration;
- developing two different measuring instrument prototypes.

The results will be used in priority by CEN TC169/WG12 in the next revision of EN 13201 series (mainly part 3) or as an addendum, by CIE – TC4-50 and related technical committees [CIE TC4-51] and by the whole EU lighting engineering community, testing laboratories and road authorities.

### *B. Structure of the project*

The project is structured with three technical work packages as shown in Figure 1:

- WP1 devoted to Instruments,
- WP2 devoted to Applications
- WP3 dedicated to Guidelines and database.

Two more work packages take care of *Impact* and *Management.*

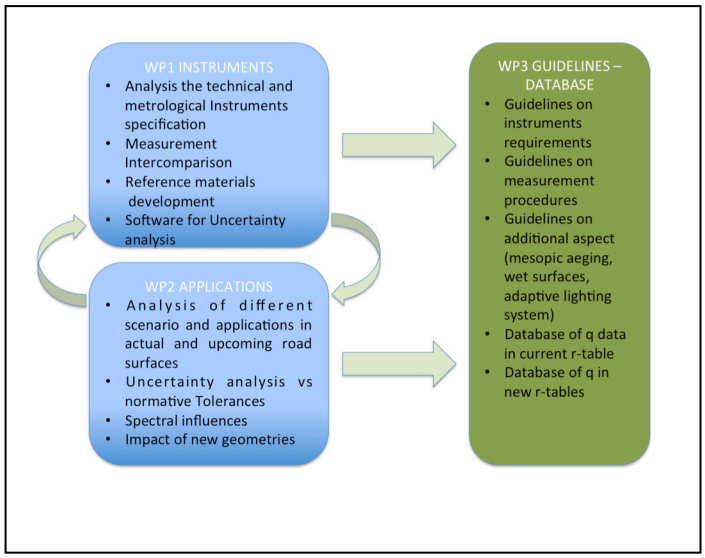


Figure 1. Technical workpackages of JRP SURFACE project

*1) WP1*

The aim of this work package is to propose technical and metrological specifications for instruments used to measure luminance and (reduced) luminance coefficients of road surfaces in laboratories or on-site, including methodologies for calibration, establishing traceability and evaluating the measurement uncertainty in order to support EN 13201 'Road Lighting', its future revisions and evolution.

The tasks are organized to consider the peculiarities of laboratory measurements, carried out with especially design gonio-photometer on small samples of the road surface, and on site measurements, generally carried out with portable instruments often not able to completely satisfy the standard geometrical constrains.

The measurement traceability and measurement uncertainty of instruments are analysed comparing the different measurement approaches and giving guidelines that will be tested during an intercomparison where real road samples and a set of reference samples are measured by several laboratories.

Generally the measurement of the spectral radiance coefficient is not considered due to the high cost of the requires instrumentations and technical difficulties, but in actual road lighting installations different light sources are used, e.g. high, medium and low correlated colour temperature LED, metal halide lamps, high and low pressure sodium lamps. For this reason it is important to analyse and quantify discrepancies that can rise when the spectral emission of the light source used in the instrument is different from the spectral emission of the lamp used in the road lighting installation.

*2) WP2*

The aim of this work package is to analyse the different scenarios and applications related to luminance and (reduced) luminance coefficients of road surfaces in order to propose optimised measurement geometries for the characterisation of photometric quantities for road surface materials to support EN 13201 'Road Lighting', its future revisions and evolution.

It will address the need for improved *r*-tables of data representative of present road surface materials and of geometries, optimised for existing road lighting sources and luminaires, in order to satisfy the requirements of standards on spilled light and light pollution. WP2 will also analyse different road lighting situations to provide the geometrical and spectral factors that need to be addressed to define new angular reference conditions (new geometries) useful for current lighting installation and future implementation of smart lighting and mesopic concepts.

Further to this, the application of EN13201-4 requirements on tolerance analysis will be studied by software simulations and perceptive experiments using virtual driving simulator of OPTIS partner. As well Cerema and ZEHNTNER partners will develop their own instrument initial version.

*3) WP3*

The aim of this task is to develop pre-normative guidelines and provide the missing data in *r*-table of current standards and to provide research results and guidelines for the future evolution of European and National standards about road lighting.

Using results of WP1 and WP2 where the single problems are deeply considered and justified, here the goals are to create documents in a normative layout that are a sound contribution to the standards development work of CEN working groups:

- CEN TC169/WG12 for application aspects in the design of road lighting installations and in the tolerance evaluation of the project to reduce and minimize the over-dimensioning of installations,
- CEN TC169/WG7 for the metrological aspects and traceability of instruments.

The same results, joint to worldwide contributions, will be used at CIE Technical committee TC4-50 and could be discussed in ISO TC274 where the "Road reflection properties" is an item in the list of priority topics. The quick dissemination of the results to the SDO is assured by the actions of WP4 and by the strong involvement consortium members in the aforesaid SDO, TC and WG.

The definition of a database (*r*-tables will be an extract of it) will improve the availability of new data considering both traditional and new geometries. It will permit the comparison of measurements and studies considering important aspects like wet/dry conditions, aging and spectral influence. It will also facilitate the adoption of standard *r*-tables that are useful as starting step in the design of road lighting installation or when detailed measurements are not possible or available

*4) WP4*

This task (impact) will assure that the results achieved in the technical work packages of the project are effectively communicated to the interested standardization bodies, stakeholders, collaborators and lighting designers communities including instrument manufacturers and software houses.

The consortium will organize training courses, and training material like electronic brochure. Two different symposia on road surface characterisation will be organized under CIE aegis.

## III. IMPACT OF THE PROJECT ON THE EU COMMUNITY

The project will define new optimized measurements geometries of luminance coefficient and up-to-date reference data for calculation. Only the availability of reliable reference data of actual (or oncoming) road materials will allow lighting designers to gather the energy savings and quality parameters forecasted in the standards and the EU commitment to cut energy consumption by 20% by 2020 (Key Performances Target) [9] providing to all users a more efficient and safe road lighting.

It will also strengthen the turnover of old lighting luminaires with new SSL luminaires that combined with adaptive system controls allow to reach energy savings up to 70%. Savings on road lighting have strong impact on country budget because lighting consumption can amount up to 50% of public electrical consumption in Cities.

The project guidelines, the full set of new reference data, the instrument prototypes will stimulate the European market to provide adequate portable measuring instruments for on site characterization: due to the lack of reference data, current EN standards do not consider compulsory on site evaluation of *q*. The industries will be also to stimulate through the realisation of Certified Reference Materials for calibration of portable device and road lighting verification.

The guidelines on measurement uncertainty and measurement methodologies and especially the planned intercomparison will stress and improve the measuring capabilities of NMI goniometers to materials that are far away from the Reference Materials normally used in metrology (e.g. ceramic tiles or lambertian surfaces) for units maintenance and dissemination.

The CIE scientific community, especially Div 4 community, will receive new fresh contribution to TC4-50 and TC4-51 works. Two different workshops on road surface characterisation are planned: one at the start of the project to endorse the project and stakeholder committee during the next CIE mid term Session meeting in October 2017 and one at the end of the project to disseminate the results under the aegis of CIE.

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## REFERENCES

[1] *Road lighting. Performance requirements*, CEN EN 13201-2: 2015, 2015
[2] *Road lighting Calculation of performance*, CEN EN 13201-3: 2015, 2015
[3] *Road lighting Methods of measuring lighting performances*, CEN EN 13201-4: 2015, 2015
[4] *Road lighting Energy performance indicators*, CEN EN 13201-5: 2015, 2015
[5] *Road Surface and Road Marking Reflection Characteristics*, CIE 144:2001, 2001
[6] C. Chain, F. Lopez, P. Verny. " Impact of real road photometry on public lighting design" in Proc. CIE 26th Session, Beijing. 2007
[7] *Recommended System for Mesopic Photometry Based on Visual Performance*, CIE 191:2010, 2010
[8] *The Effect of Spectral Power Distribution on Lighting for Urban and Pedestrian Areas*, CIE 206:2014, 2014
[9] http://ec.europa.eu/eurostat/statisticsexplained/index.php/Information_society_statistics_at_regional_level