Abstract – This paper focuses on intelligent road lighting measurements and road lighting control. In today’s devices, luminance and color measuring cameras are attached to high-quality Charge Coupled Devices (CCD) of digital cameras, each of which should be properly analyzed, calibrated and adapted to the light measurement [1]. Light-measuring technology has developed into an important branch of light-measuring engineering. This technology provides effective solutions to a variety of tasks in the field of light-measuring. Modern measurement applications enable us to control and determine the best outdoor lighting levels and management options.

On the other hand, with an effective road lighting control system, electricity can be saved without adversely affecting either the safety of driving or the quality of road lighting. The dimensioning and investigation of different weather conditions and their effects on drivers’ visibility offer new ways to optimize road lighting via intelligent control.

I. INTRODUCTION

Road lighting is a practical tool for ensuring good visibility conditions in night-time driving. So far, road surface luminance has been based on standardized lighting classes, using certain static luminance levels in certain road types [2]. In practice, however, luminance levels of road surfaces are usually very dynamic and depend to a large extent on many external factors, such as weather conditions, buildings along roadside, ambient brightness, road surface uniformity and materials etc. For example, in Estonia during wintertime the intensity of road lighting is often excessive in relationship to the standard requirements because of the snow. Recent increases in the cost of electrical energy have caused actions to minimize energy costs. Activities of technological research and development have been carried out to find solutions and coherent guidelines for intelligent road lighting control.

II. MEASUREMENTS

A. Measurement Method and Equipment

Road lighting calculations and measurements in Europe follow the European standard EN 13201-3 [3]. In this work road lighting was measured and calculated according to the standard. All the measurements were made using the luminance meter Konica Minolta LS-100 and the luminance photometer TechnoTeam LMK 98-3 and LMK LabSoft Standard 11.5.2 computer programs. The LMK 98-3 luminance photometer is a computer controlled CCD-based imaging photometer, which is applicable to luminance measurements and analysis in indoor and outdoor lighting. The photometer consists of a Sony ICX 285 AL sensor cooled 12-bit CCD camera, a set of four full filters and a choice of lenses. The photometer is controlled by LabSoft software. The system accuracy for luminance measurements is ± 3 %.

The dependence of the measuring range on the lens is 0.1 ... 10000 cd/m² [5].

B. Instrument Requirements

The International Commission on Illumination (abbreviated as CIE from its French title) is an organization promoting international cooperation and exchange of information between its member countries on all matters relating to the science and art of lighting. In accordance with an agreement between ISO (the International Organization for Standardization) and CIE, standards are published as double logo standards by ISO. Standards produced by the CIE are a concise documentation of data defining aspects of light and lighting, for which international harmony requires a unique definition. CIE Standards are therefore a primary source of internationally accepted and agreed data which can be taken, essentially unaltered, into universal standard systems. Based on the German standard, DIN 5032 /7 Light Measurement Classifications are for luminance and brightness measurement instruments. There are four classes of luminance meters by the German DIN 5032 standard: L, A, B and C. Requirements for type F (field instruments) meters for the measurement of planar luminance are specified in classes A, B and C.

In these measurement tests, the instrumentation used is in Class A.

C. Road Lighting Measurement with LMK Camera

Luminance measuring camera LMK 98-3 (Fig.1) designed by the TechnoTeam company uses high-quality CCD, calibrated and finally adapted to the light measurement. Thus, the signal values in the image can be converted directly into luminance values. The camera and its CCD chip are optimized to measure luminances accurately. This includes the spectral V(λ)-correction, shading correction, compensation of dark current and temperature-drift, as well as the absolute calibration of the system. The luminance and the color values can be directly obtained from the luminance and color images, respectively. For doing this, the LMK software offers numerous functions, which permit the user to evaluate and display luminance sectional views, histograms and simple statistics (mean value, variance, minimum, maximum) to analyze the luminances as a function of the luminance or the environment. The LMK image evaluation software provides a module for the projective rectification of evaluation regions, which makes it possible to convert metrological information to the x-y-coordinate system.

We decided to choose the LMK 98-3 camera as the best solution for measuring the light source of the image of the internally illuminated object at a glance in the Laboratory of Lighting Technology at Tallinn University of Technology.

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No repetition of the measurements is required, if a more detailed image is the case. All the measuring data are achieved at the same time. The luminance picture can be saved and allows a later data iteration. Pseudocolor (every color on the linear scaled range of colors means one luminance value) pictures can be stored on media (CD-ROM, DVD-ROM) and then later an object can be measured on a computer screen.

III. EXAMPLE OF MEASUREMENT

A. Measuring Streetlighting with Dimmable LED Lights

We used a photographing luminance camera to measure street lighting. The purpose was to confirm if the luminance conforms to the standard and to find possible levels of dimming to achieve the best combined result of sufficient lighting, uniformity and savings. Photograph measuring fixes the records for possible remeasuring of data from the records. Choosing different areas from measuring picture it is possible to judge separately luminance for pedestrian crossings, light traffic areas, effect of advertising or buildings to luminance etc.

Measurements were carried out in Tartu on streets with dimmable LED lights. Here we present measurements from one example street. We used the photographing luminance camera LKM 98-3 Color mounted on a tripod and chose sections of street that were free from additional light noise. Regardless of the width of the street and distance on lighting fixtures, the measuring raster was 60 points.

Camera position was chosen based on the width of the road and the number of lanes. With special software LMK LabSoft it is possible to retrieve luminance values from the photos taken and as a result prepare different measuring scenarios. Average overall uniformity and longitudinal uniformity luminance measurements are based on the European standard 13201-4 [4]. Measurements were done on the height of 1.5 m, from the center of the measuring area and 60 m from the front edge of the area. If this had been done with single point measuring, it would have taken tens of individual measurements and much time. All the data were collected with a single aimed and focused photo using the photographing luminance camera. From the photo program, luminance graphs were composed in pseudo colors. On these graphs it possible to select points where otherwise single point measurements would be needed. Therefore, this method gives a significant time saving [7].

Measurements done with the photographing luminance camera are in compact pictures available for analyses. Areas for measuring were chosen between two light sources in a row as well as in view of minimizing external light sources, avoiding bright areas on the road surface (color marks etc.). After taking pictures, data were analyzed with the Labsoft program. All pseudo color pictures were transferred to a planar graph and from that the program calculated average overall uniformity and longitudinal uniformity of luminance.

To double-check the measurements, we used the Konica-Minolta CS-100 handheld point measuring device. Measurements were taken in the same area where main measurements were conducted and in the same points as used later on the data collection from the pictures. These data were recorded manually. Collected data are presented in Table I.
### TABLE I
LUMINANCE MEASUREMENT RESULTS
ON THE VABADUSE AVENUE

<table>
<thead>
<tr>
<th>Lamp power level</th>
<th>Class</th>
<th>Standard EN-13201-2:2003</th>
<th>Measurement results</th>
</tr>
</thead>
<tbody>
<tr>
<td>107W lamp</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dimmed to 100 W</td>
<td>ME4b</td>
<td>0.75, 0.4, 0.5</td>
<td>1.9, 0.3, 0.5</td>
</tr>
<tr>
<td>Dimmed to 50W</td>
<td>ME4b</td>
<td>0.75, 0.4, 0.5</td>
<td>1.4, 0.5, 0.5</td>
</tr>
<tr>
<td>Dimmed to 30W</td>
<td>ME4b</td>
<td>0.75, 0.4, 0.5</td>
<td>1.0, 0.5, 0.5</td>
</tr>
</tbody>
</table>

### IV. CONCLUSION

Street luminance measuring with a photographing luminance camera and control measurement with a handheld point device enables us to provide an overview of dimming possibilities. The photographing camera allows time saving, is easier to handle and provides a better overview of luminance situation in the measuring area compared to point measuring. In new lightning projects with dimmable lights it is possible to perform promptly measurements and adjust luminance levels. In our example, the original luminance levels were unnecessarily high by standard and local authorities were able to lower the lighting level to meet the standard. In this specific situation, the surrounding lights had an influence and lighting was lowered to 50 W level.

During 2015 this measuring method is planned to be used on streets with new dimmable LED lights in seven cities. Our measurements enable saving from the lighting level, ensuring more even lighting on the street surface, lowering light pollution and therefore eventually assuring safer driving conditions.

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### REFERENCES