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THE ROLE OF GIS IN ENERGY AUDIT OF PUBLIC LIGHTING

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Abstract: Public lighting is a small but very important part of electricity consumption in every country. Energy audit of public lighting is one way of fulfilling energy policy of EU and is a legal obligation in Croatia since 2014. The audit must be conducted every 5 years according to the Ordinance on energy audits of buildings and energy certification of buildings which regulates the obligation to conduct energy audits of public lighting. Auditing is done according to the national methodology for energy audits of buildings. Geographic Information System is not specified as a tool for energy audit but in practice it is very useful. This paper describes the usage of open source GIS tools in energy auditing of public lighting system.
Keywords:energy audit, GIS, public lighting system

INTRODUCTION

Public lighting (PL) is a very important part of electricity consumption in every country. PL has an aspect of security, because it provides visual conditions which ensure normal transport and communication in public traffic areas. Furthermore, a very specific aspect of PL is providing the psychological and physical safety of people and property. Another aspect of PL importance is generation of specific aesthetic atmosphere and attractiveness of inhabited areas (illumination of squares, parks, buildings and monuments) [1]. Public lighting represents 0.1 percent of total energy consumption, but its significance is far greater than the modest energy representation. Street lighting must meet criteria to ensure visibility, visual comfort and energy efficiency that must be considered in the designing process. Requirements for public lighting, especially road lighting are defined with EN 13201 [2]. As an example for the writing of this paper, the energy audit of a small lighting system with four supply point and 135 lamps was taken. In order to prepare a report on the conducted energy audit, GIS tool was used for mapping of system components. Energy audit conducted according to methodology includes: gathering basic information about the user, the analysis of available project documentation, a description of the public lighting system with mapping of the existing installation, measuring the existing light quantities, measuring electrical quantities, the analysis of energy consumption bills and proposal for measures to improve energy efficiency.

TECHNICAL REQUIREMENTS ON PUBLIC LIGHTING

The basic aspects of PL can be divided into three areas:

1. Functionality - the primary function is to provide the minimum required uniform illumination values without discomfort glare;
2. Aesthetics -the play of light and shadow creates a special atmosphere;
3. Cost-effectiveness - the total cost includes the cost of construction, design, management, maintenance and energy required for the unobstructed operation.

PL Functionality

Functionality refers to obtaining luminance levels, luminance uniformity, degree of glare limitation, lamp spectra and effectiveness of the visual guidance. Level of luminance isn't important as uniformity and spectra, because of scotopic/photopic characteristics of the eye [2].

Cost-effectiveness

Cost-effective criteria is based on the efficiency of the used light source. Classic light sources (based on incandescent) are gradually eliminated in the EU (the Directive on Energy Efficiency). There is a large variety of modern light sources on the market. For PL purposes, the following contemporary light sources are available:

- ✓ High-pressure sodium (HPS) 80-140 lm/W, CRI 20-30; 1900-2800 K, life time 10,000 - 24,000h
- ✓ Metal-halide lamp 100 lm/W, CRI 68, 4000-5000 K, life time 20.000h
- ✓ Mercury-vapour lamp (abandoning technology) 30-60 lm/W, CRI 20-60, 6800 K life time 20,000
- ✓ Fluorescent 45-105 lm/W, CRI 65-75, life time 10,000 - 45,000h
- ✓ LED/OLED 115 lm/W, CRI 65-75, 6500 K, life time - 50,000h
- ✓ Light Emitting Plasma HEP/LEP 120 lm/W, CRI 75-90, 5600 K, life time 50,000h

Color Rendering Index (CRI) is a measurement of a light source's accuracy in rendering different colors. Requirements which are placed on the lamp are in compliance with standards, proper distribution of *the light output, glare limitation (through shaping and shading, the cut-off, semi cut-off, not cut off) and mechanical consistency [1].*

MAPPING OF PL

There are numerous ways to map installation, the easiest one is to use GSM smart phone with GPS. Accuracy of public GPS systems is in the range of 3 to 10 meters. In areas with distance between lamps of 30 meters, this is quite satisfactory. Mapping of existing installation is done with Android Open Street Map tracker application which exports data in GPX format with waypoints that we entered during audit [3]. Small change is made in the optional xml file (more info in [4]) to provide the necessary menu entries for PL, as can be seen in Fig. 1.

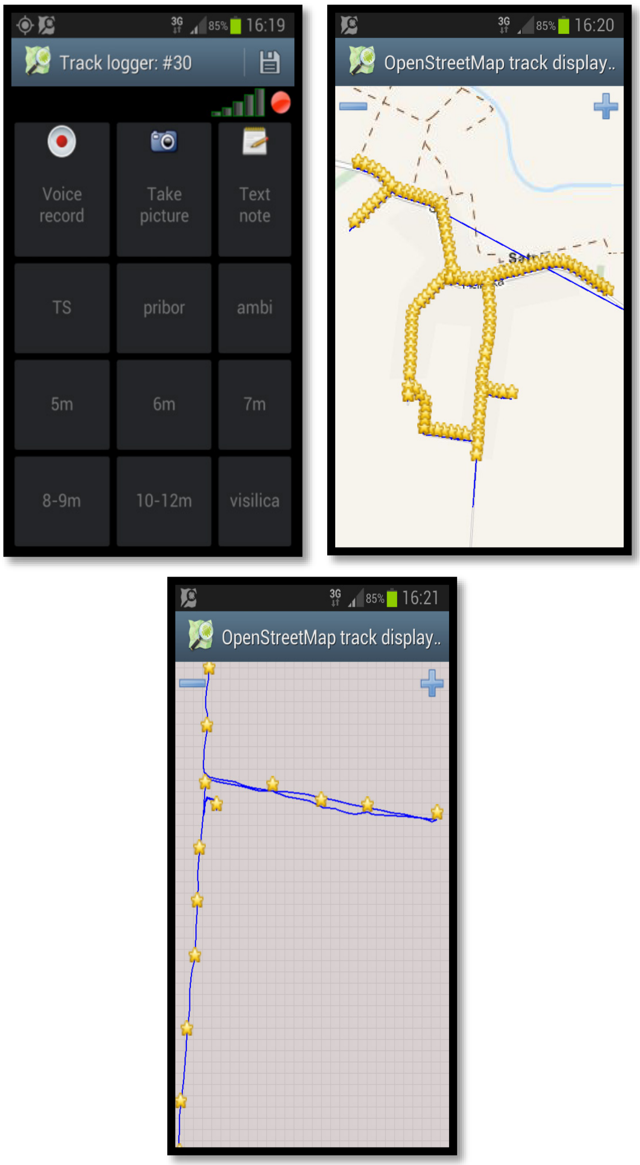

Figure 1. *OpenStreetMap tracker layout, mapped PL system and mapped details*

We found that layouts customization should be done after walk-through audit in order to ensure optimal layout menu that matches with the system elements on field. During tracking it is important not to enter elements twice and to check that tapped element is correctly entered (wait for the confirmation). After finishing mapping we can upload data to open street map server or download the GPX file on computer.

GIS data processing

Data collected by mapping is exported (in GPX file) as the GPS Exchange Format that can be reviewed as a text but it is more useful to use GIS editor. In Fig. 2. we can see waypoints for collected data: latitude, longitude, elevation, time and name of waypoint. Name reveals type of lamp, High Pressure Sodium, power of lamp 150 W, producer of lamp, power supply through self supporting cable bundle SKS and height of the concrete pillar. There are other data in the GPX file, but for the energy audit, waypoint is data that we entered through OpenStreetMap tracker layout.


```
<?xml version="1.0" encoding="UTF-8" ?>
<gpx xmlns="http://www.topografix.com/GPX/1/1" version="1.1" creator="OSMTracker
for Android" - http://osmtracker-android.googlecode.com/"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://www.topografix.com/GPX/1/1
http://www.topografix.com/GPX/1/1/gpx.xsd ">
        <wpt lat="45.60629473999143" lon="18.491377690806985">
                <ele>142.29998779296875</ele>
                <time>2014-04-02T14:12:32Z</time>
                <name><![CDATA[HPS-150W_TEP-SKS-concrete8m]]></name>
                <sat>0</sat>
                <hdop>1.25</hdop>
        </wpt>
        <wpt lat="45.60673650819808" lon="18.491428904235363">
                <ele>146.4000244140625</ele>
                <time>2014-04-02T14:13:38Z</time>
                <name><![CDATA[HPS-150W_TEP-SKS-concrete8m]]></name>
                <sat>0</sat>
```


Figure 2. *Insight into the GPX file*

Benefit of GIS usage can be seen when we open GPX file in GIS editor. For this propose we used QGIS a free and open source Geographic Information System [5]. We could use JOSM, an extensible editor for OpenStreetMap (OSM) written in Java, but QGIS provides much more for further PL analysis. On Fig. 3 it can be seen open GPX file.

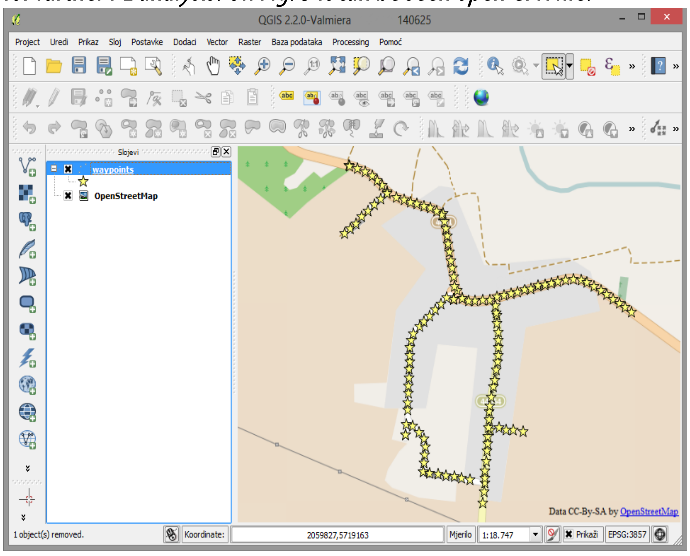

Figure 3. *Data from GPX file in QGIS*

Entering in attribute table of waypoints and grouping according to the attributes new layers can be made as presented on Fig. 4. Comparing Fig. 3 and 4., we can notice that some elements are missing, better to say we did not see lamps in two side streets during first round of mapping. In the second round, they are mapped and merged with existing records.

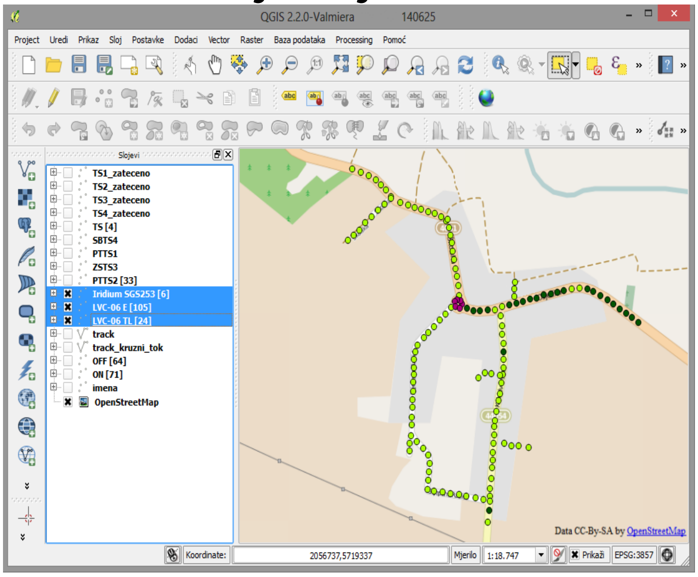

***Figure 4.** Newly created layers with lamps types and position*

Highlighted layers on the left side contain position of three type of lamps that we accounted during the audit. As can be read, there are 6 Philips Iridum, 105 TEP LVC-06E and 24 TEP LVC-06TL lamps installed in the system. In order to define zones of lighting, electrical measures were made in supply points. In order to define zones of lighting, electrical measures were made in transformer stations on all PL lines. During measurement on active line, active lamps are marked visually in order to define zone of lighting. Energy balance must be determined, measured power in supply point must correspond to the consumption of active lamps. It is important to note two things. First, measurement must be performed when the system enters the steady state, 6-12 minutes after switching on depending on the type of lamps. Second, while analyzing energy balance consumption, ballast and all possible losses must be taken into account. After measurement, we come to the situation shown in Fig. 5. newly created layers with supply points and PL zones.

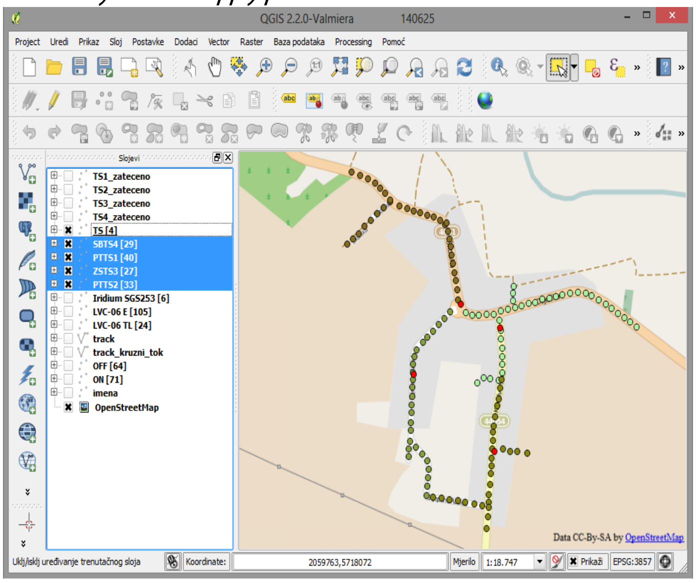

***Figure 5.** Newly created layers with supply points and PL zones*

Once becoming familiar with the system, its zones and electricity consumption, the only thing remaining is to determine the light levels on road surface. Measurements must be conducted during night while system is in function and traffic is minimal. Data obtained by measurements of illumination is mapped in order to determine position of lamps with failure or poor maintaining. Fig. 5 presents lighting levels in lx measured on road surface. As we can see from Fig. 6 every second lamp is out of function due to savings of electricity. Turning off every second lamp is not a recommended measure, because a decrease of luminance uniformity results in a longer time required to spot objects on road.

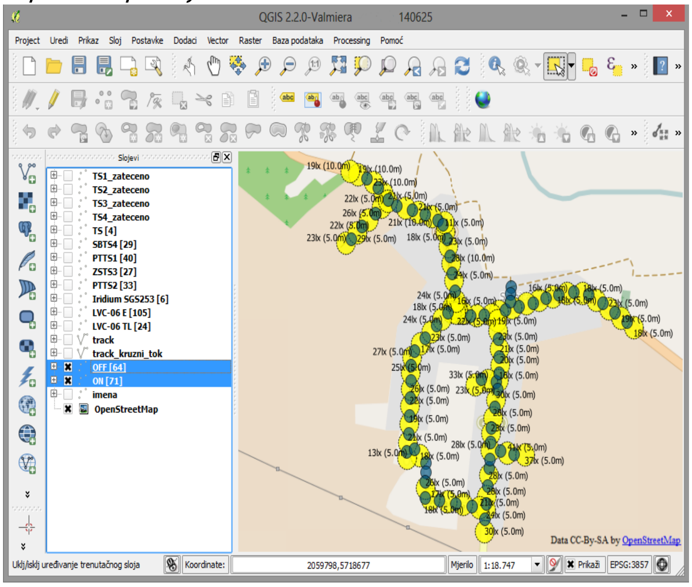

***Figure 6.** Layers with illumination measurement data*

In addition to the usage presented above, GIS can be used for geo-tagging of photo documentation, which is an integral part of every energy audit. Easiest way is to use camera with GPS but pictures can be added manualy on mapped lamps. Fig. 7. presents photos taken with camera that have integrated GPS. Documented lamps on picture represents position of poorly maintained lamps.

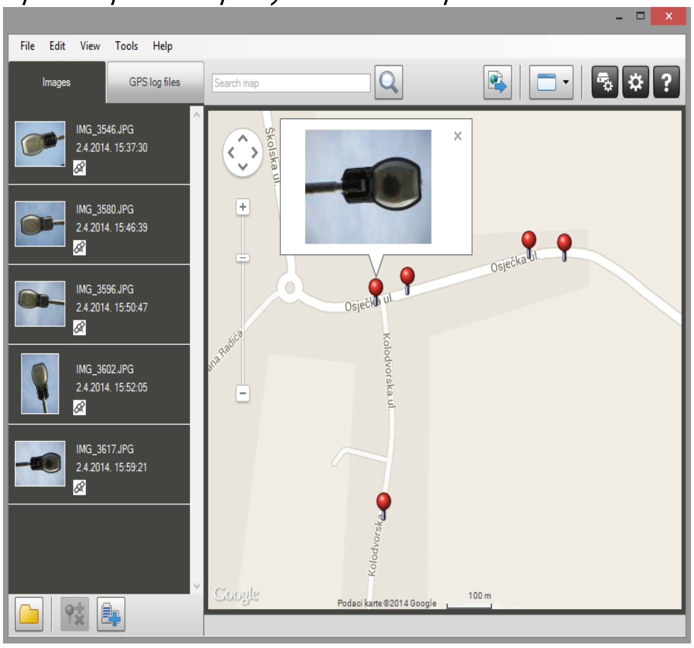

***Figure 7.** Layers with illumination measurement data*

CONCLUSION

Public lighting is important because it provides visual conditions for normal transport and communications in public traffic areas. In

Croatia, the Act on Energy Efficiency in Direct Consumption is an ordinance on energy audits of buildings and energy certification of buildings. The ordinance lays down the obligation to conduct energy audits of public lighting every 5 years. An energy audit is a systematic process of acquiring the appropriate knowledge about existing energy consumption, and can be performed only by an authorized physical person or legal entity. PL infrastructure includes: lamp posts, lighting fixtures, light sources and management system. Mapping of the lighting system is the easiest way to conduct energy audit of PL because collected data is momentary digitalized.

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