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Aleksandar Mastilovic, MSc[1]
E-mail: amastilovic@rak.ba

Osman Lindov, PhD [2]
E-mail: olindov@gmail.com

[1] Communications Regulatory Agency Bosnia and Herzegovina
Mehmeda Spahe 1, Sarajevo, BiH

[2] Faculty of Traffic and Communications University of Sarajevo
Zmaja od Bosne 8, Sarajevo, BiH

URBAN SUSTAINABILITY AND SMART STREET LIGHTS CASE STUDY SARAJEVO

Key Words

Sustainability;
Streetlights;
Air pollution;
Entrepreneurship

Abstract

Smart Cities concept is a complex system that uses the ICT solutions and the IoT hardware devices to collect data and optimize the city management process focusing on improvement of the Quality of Life for citizens. ICT-driven solutions involve “smartness” in current services based on data analytics, finding a new knowledge using machine learning, and artificial intelligence for optimization of resource allocation. This paper describes the methodology, management, and benefits of the smart public lighting system proposed for the City of Sarajevo in the Call for Proposals on Smart Sarajevo in the City Mind Lab initiative by the UNDP Bosnia and Herzegovina and the City Council. Aims of the smart public lighting system are to decrease the power consumption as a primary goal, but also to enable reaching secondary goals as an air and light pollution decreasing and many others. The collected open data is the crucial catalyst for launching the entrepreneurship ecosystem and the economic growth in the City. This vision is a part of the EU vision in the concept of Open Innovation 2.0, known as the Quadruple Helix model, which engages all community sectors as a government, industry, academy, and civil society. The paper describes the case study for the City of Sarajevo and the general survey of opportunities and benefits of the smart public lighting system implementation.

1. INTRODUCTION

Public Lighting System aims to decrease power consumption, air pollution, and light pollution to improve public service delivery. In Sarajevo, a lot of city's energy expenditure goes to street lighting. When times are lean, energy efficiency is becoming increasingly important. The aim is also to keep maintenance costs under control. Investing in energy-saving measures with intelligent street lighting, therefore, seems a logical step. Even the transition to LED lighting is still not a visible development, but it could be a first step forward.

Our project proposal revolved around Smart Public Lighting System aims to decrease the power consumption, air, and light pollution to improve public service delivery, i.e., street lightning and help address the priority city challenges. Besides primary benefits, there are many secondary and tertiary benefits of the Smart Public Lighting System implementation. The collected data could be defined as Open Data licensed what means that the data or at least some part of them could be published and made available to analyze from the third-party subjects. Many upcoming start-ups related to new and smart ICT-based solution in hardware and software topics find this very useful, what directly affects the entrepreneurship ecosystem and affects the economic growth in the City.

2. SMART CITY: CASE STUDY – CITY OF SARAJEVO

Technology-driven Smart City concept is a response to challenges that many cities face, such as lower ICT use level, unemployment, weak infrastructure, socio-economics inclusion, increasing competition, and many others.

A city becomes "smart" when investments in human and social capital and traditional transport and ICT-driven communications infrastructure fuel sustainable economic growth and high quality of life, with a wise management of natural resources, through participatory governance. Smart City system strikes a balance between economic, social, and environmental demands, focused on Smart Sustainable Green Growth, recognizing economic growth and sustainability as welfare prerequisites.

The City of Sarajevo, urban and suburban area, is characterized by good development potential of the Green Growth sector. Focused interventions on highly innovative Smart City themes can enhance innovation level in the area lagging behind the EU average, implementing UN Sustainable Development 2030 Agenda and EU Digital Agenda 2020 strategies.

In the City of Sarajevo, a lot of city’s energy expenditure goes to street lighting. When times are lean, energy efficiency is becoming increasingly important. The aim is also to keep maintenance costs under control. Investing in energy-saving measures with intelligent street lighting, therefore, seems a logical step, but it does not assume the current situation in this respect. Even the transition to LED lighting is still not a visible development, but it means a first step forward.

Since the City of Sarajevo is in the early stage of Smart City launching and one of the most important priorities is the public lighting system. The Public Lighting System (“System”) in the City of Sarajevo is a conventional old-fashion system with a very low or not-at-all modern ICT-driven solution present. It means that there is no bidirectional transfer of information on the current state of the system to any of the potential stakeholders in the process of the City public services management. Some and minimal overview of the state of the system exists in the Power company, which monitors its system from the aspect of power flow and state estimation perspective.

Additional savings and improvements are defined as follows. This approach understands that the Public Lightning System is not fixed anymore on 100% power all the time, and the System should be connected with some other parameters. The System is working in time cycles setting the power level on more than one e.g., 100-70-40-20% of maximum power or any other regime. Transitions could be defined by timer e.g., every 3 minutes until pedestrian or car appears what triggers the System to go back to the maximum level 100% power. Power levels and length of time cycle is the subject of the optimization process during the implementation and operation phases [1].

The System is currently designed to work with the predefined schedule in manual or semi-automatic mode with limited installations of photocells in some location, which can regulate the timing of the System turning on and off. In some plans for future implementations and minimal current implementations, there is an option for remote control of the System. Both solutions are very limited to the conventional framework of the Public Lighting System without any autonomous self-regulation, collecting data, and sending feedback to the operating centers [1].

The new System enhanced by intelligent self-regulating mechanism and with the quick response to citizens' habits and profiles of their needs should deliver the optimal quality of service, increasing the total efficiency of the System based on a data-driven decision from the data center. The System is connected in bidirectional communications mode with the data center(s) where the collected data is stored for the analysis and calculating optimal decision, using Artificial Intelligence and Machine Learning algorithms and advanced mathematical techniques as a response on real needs in the real-time. That means that the data-driven decision making can deliver the maximal quality of service and the Quality of Life for the citizens against the power consumption and environmental degradation. This trade-off is possible by collecting the relevant group of parameters for deterministic mathematical-based calculations.

The essential data to be collected are the daylight period depending mostly on the period of a year. Current weather state, intensity of presence of pedestrians and traffic in the location, profiling citizens habits by hours (e.g., intensity is lower during the night hours), days (e.g., citizens are more active during weekends), months (e.g., citizens are more active during the summer period) become the set of data critical for further analysis and decision making. The collected data may prove some additional presumptions.

The total effect prediction for the ICT-driven Smart Public Lighting is expected no worse than decreasing the power consumption by up to 38%, decreasing air pollution up to 150%, decreasing the light pollution up to 300%. It depends on the very local current state and the level of implementation of all intelligent functions.

Besides primary benefits, there are many secondary and tertiary benefits of the Smart Public Lighting System implementation. The collected data could be defined as Open Data licensed what means that the data or at least some part of them could be published and made available to analyze from the third-party subject. That includes many upcoming start-ups related to new and smart ICT-based solution in hardware and software topics what directly affects the entrepreneurship ecosystem and affects the economic growth in the City.

3. SMART PUBLIC LIGHTS FOR TRAFFIC SAFETY

Nature and buildings shape the environment of urban traffic participants during the day. In the night, artificial light is an additional factor that determines the perception of the environment and object, their shapes, size/volume, position, and space. The illumination of roads and their immediate surroundings allows visibility, orientation, and safety of the mobility of both motor and pedestrian and bicycle traffic. The use of vertical and horizontal light of different luminosities and colors of light, and light and shadows determine the ambiance through which traffic participants move in night conditions.

Illuminations of roads and their more extensive areas are an element of the environment that assists in the overall flow of safe traffic, and if properly positioned, will result in better detection and detection of obstacles and dangers on and off the road.

Traffic participants rely on their observation, defined as the ability to detect and respond to visual information during movement, which provides them with their safety of movement. The reliability of observations depends mostly on the ability to spot details and changes in the field of view.

The primary function of traffic lights and the environment is to ensure a minimum prescribed value of illumination, uniform illumination, and reduce the effect of the headlamps. Traffic lighting and the surrounding area should allow for such conditions of vision that guarantee the following at night:

- safer rides for drivers
- observing potential hazards, better orientation, and getting the impression of safety when walking for pedestrians and cyclists
- observation of the whole and essential details in the visual environment of traffic participants.

When driving at night, the visibility length depends on the illumination: light sources on the vehicle front or the constant lighting of the roads or their combination. By decreasing general illumination, most of the essential visual functions, e.g., visual acuity, contrast sensitivity, depth of vision, speed of observation, color differentiation, are gradually diminished and lost.

The illumination of the road must be such that the driver recognizes in time any obstacle, has sufficient visibility, and is sure of the traffic on the road. It is necessary to ensure the uniformity of street lighting and highlight critical points, e.g., pedestrian and bicycle crossings, crossings, bridges, turns.

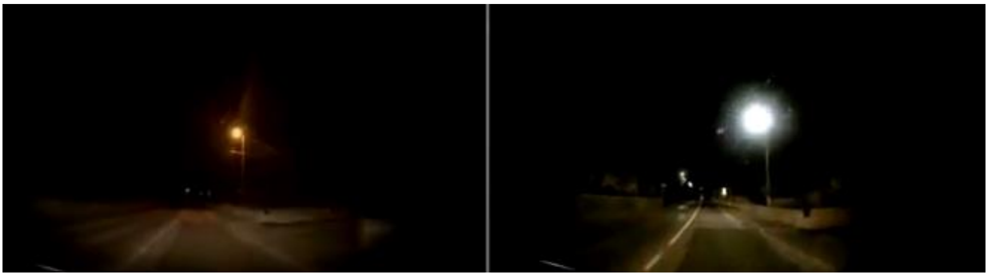

Figure 1. Conventional vs. LED Illuminations on the road

The lighting of the road from the aspect of driving must satisfy the following conditions:

- the road must be visible in full detail when driving,
- the route of the road must be visible and marked visually, equipped with various aids, such as signposts, curb lines,
- all hazardous locations should be highlighted so that the driver can notice them on time,
- visibility comfort must be ensured to prevent the driver from straining while driving,
- uniform lighting of the entire road should be provided,
- all horizontal and vertical signage and other devices must be visible and must not blind the driver.

Currently, there are a significant number of cities in the world that have implemented the intelligent traffic light system. The City of San Diego (CA, USA), with the help of a wireless remote control and monitoring system for 3000 streetlights, saves more than $ 250.000,00 per year in electricity and maintenance costs over the conventional system of public lights. The City of Oslo (Norway), has reduced energy consumption by 70% and CO2 emissions by 1440 tones per year by introducing innovative and energy-efficient street lighting with 10.000 installed sodium lights, which adjusts the light as needed using an intelligent lighting system [3].

Each public lighting system shall comply with EN-13201 European Standard for Road Lighting Systems. This standard defines the classes (types, categories) of illuminated roads and visibility requirements, as well as methods for measuring and evaluating the characteristics of road lighting systems. The group of standards EN-13201 is adopted in the regulations in Bosnia and Herzegovina as BAS-13201, as it follows:

- BAS/EN-13201-1:2017: Road lighting Part 1: Guidelines on selection of lighting classes,
- BAS/EN-13201-2:2017: Road lighting Part 2: Performance requirements,
- BAS/EN-13201-3:2017: Road lighting Part 3: Calculation of performance,
- BAS/EN-13201-4:2017: Road lighting Part 4: Methods of measuring lighting performance,
- BAS/EN-13201-5:2017: Road lighting Part 5: Energy performance indicators [1].

From the perspective of Smart Public Lighting in the City of Sarajevo, the limitations and additional parameters noticed in the group of standards BAS/EN-13201 are added and shall be taken into account for optimal decision calculations on the working regime for the Smart Public Lighting System in the City of Sarajevo.

All details on parameters, their classes, values are presented in the group of standards. Values are correlated with the speed of movement for pedestrians and vehicles, and the level of illumination shall be aligned with these levels or better, for the moment when pedestrians or vehicles cross the street. The sensors must detect the movement of a proper object in advance to be able to analyze collected data and to send a command to increase illuminations from saving level to full power level before pedestrians or vehicles reach the street. The geographical distribution of the System, routes of roads, traffic intensity parameters, and many other factors are related to each specific environment for the deployment of the smart public lighting, and it is difficult to consider the general model.

For future analysis, it considers a few examples of critical parameters for calculations of the smart public lighting system correlated with the driver's vision abilities and speed of moving.

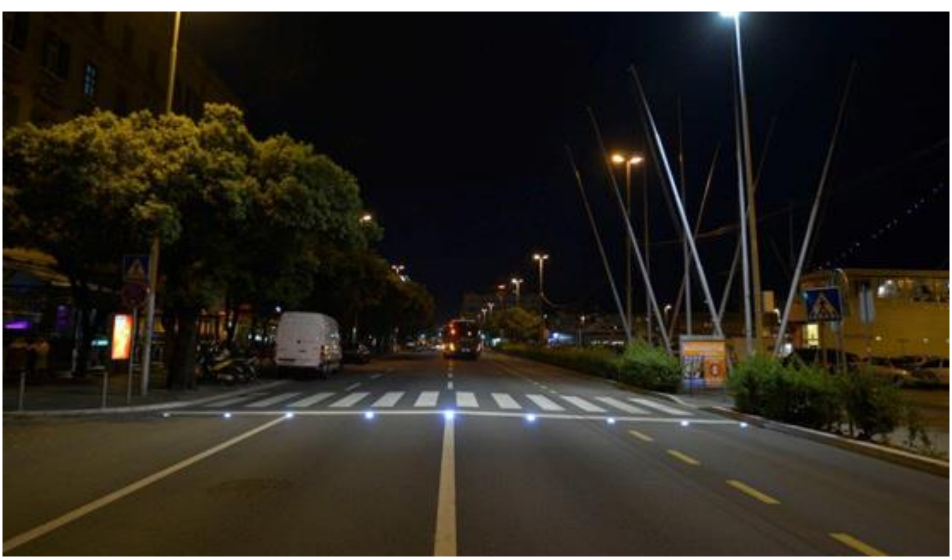

Figure 2. Public Lights in the City of Rijeka (Croatia), Pedestrian crossing signing [2]

Approximately 95% of all decisions made by the driver while driving relate to visual information. For adequate reception of visible information, the following are essential:

- width of the field of vision,
- depth of vision as well
- the ability to adapt to changes in light.

The sharpest field of vision is within 3° (degrees) of the fixation point. From 3 to 6 degrees there is an entire field of view from 6 to 10 degrees there is a right field of view (called Reading Field), from 10 to 20 ° (degrees) is a satisfactory field of view from 20 ° (degrees) and more peripheral field of view.

As the speed of movement of the vehicle increases, it changes the width of the field of view of the human driver. The field of vision narrows functionally (e.g., at a speed of 25 km/h, the width of the field of vision is about 100° (degrees) and at a speed of 100 km/h) the width of the field of vision is about 40°.

Visibility also depends on the condition of the pavement, namely on a wet and wet road, the shape of the illuminated object and space is lost, especially when the pavement surface is smooth. It is better to improve the reflective properties of the road, but to enhance the light source, thus achieving a better contrast of objects and the road while reducing blinding. The rough surface of the road is better than the smooth surface. When laying the surface of the road, the light spectrum should be as similar as possible to light in all conditions concerning the reflection of light. Causes that lead to traffic accidents in night driving conditions should assume the aspect of visibility and observation due to the elements of a vision of the individual - the driver. The ability of the eye as the most critical traffic information authority is not in all situations of equal quality. It changes according to the intensity of the light, and the lower the light, the less the eyes can see. When it comes to vision, it should know elements of driving in the evening, dawn, and night, as well as when streetlights or headlights illuminate the roadway. The sight of a driver on a well-lighted pavement is almost half worse at night than in the daytime. If the pavement is still wet in the dark, it reduces visual acuity to 1/10 of healthy vision in daylight. Reduced visual acuity results in an automatic reduction in the distance to the observed object. Reduced vision in the night is physiologically conditioned, so all this imposes the need to adjust driving visibility.

The biggest mistake is that many drivers who, regardless of age, still have a relatively good day view, find that they also see well at dusk. With the help of the “mesoptometer," it is possible to accurately measure the degree of visual efficiency in the conditions of night traffic. With changes in the organ of vision, which inevitably occurs with age and aging, it is not only a decrease in visual acuity but also a decrease in the sensitivity of the eye to contrasts, which again manifests itself in the dark. Unlike the eyes of younger people, the eyes of older drivers can only perceive striking, heavily outlined contrasts. Night contrasts play a vital role. Failure to notice the contrast often leads to a dangerous overlook of the pavement, which inevitably leads to road accidents.

Analytical or simulation model, which includes all parameters considered in this survey, is not presented in this paper, but it could be the subject for future work.

4. CONCLUSION

The design of a high-quality decision-maker software tool is a challenging task. The data center should consider tens of parameters and calculate their interactions and correlation, including different requests from the goal function. Calculation of optimal or suboptimal points of the working regime for any applications is not deterministic, and it may assume an iterative approach verified in practical application in real systems and environment.

The Smart Public Lighting System in the City of Sarajevo is the data-driven system run by the simplified model based on the goal function. It has to be optimized with the criteria of the minimal energy consumption against the length of the lifecycle of streetlight bulbs, decreasing the number of power transition and dimming as possible. At the same time, the quality of service, which includes subjective observation of citizens (pedestrians and drivers, both), has to maintain the same or similar level as it exists in the conventional public lighting system.

Additional criteria, which include the recommended level of observation from the perspective of drivers and the relation between the system management and the speed of driving, can be considered in the future upgrades of the system.

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