Features of Smart Lighting Project Implementation in the Cities of the Russian Federation

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Abstract. The research objective was to study and summarize the experience of Smart Lighting projects in the cities of the Russian Federation. As a result of the analysis of regulatory documents, it is shown that the indicator “share of street lighting controlled by the intellectual control system” is applicable to assess smart lighting projects implementation. It is shown that the Transition to smart lighting is most often based on the local action model, while the energy service contract is a popular way to finance projects. It is recognized that projects implementing lighting control functions using wireless networks are more promising.

1. Introduction  
Cities play a crucial role in the Russian economy (as of January 1, 2019, they were home to 74.5% of the country's population), but increasingly face problems that hinder their effective development: high level of wear and tear of urban infrastructure, lack of budget resources, environmental degradation, and requirements changes to the urban environment from citizens and businesses [1].  
Most of the issues associated with overcoming these problems can be solved by implementing the concept of Smart City in Russian cities.  
The concept of “smart city” has been interpreted broadly and in different ways, but in all approaches information and telecommunication technologies play a key role. Today we talk about the transition to a third generation of smart cities that are experiencing a complex digital transformation: in a smart digital city, management is based on data-driven city, which is a key element of the urban ecosystem and its individual components — smart housing and public utilities, smart energy system, smart transportation, smart health care, etc.

Since 2017, our country has been implementing a targeted state program “Digital Economy”, part of which is the “Smart City” project by the Ministry of Construction of Russia. The project is designed to increase the competitiveness of Russian cities, improve the efficiency of urban management and create a safe and comfortable environment for citizens. In 2019, the “Smart City” project became mandatory under two programmes at once: “Digital Economy” and “Housing and Urban Environment”. The list of 58 Russian cities implementing the project in the pilot mode has been compiled [2].

In terms of development of smart cities Russia is significantly inferior to the leading economies of the world, and the projects implemented in the country are mainly related to the point digitalization and intellectualization of certain urban services and infrastructures [1]. Despite this, in some Russian cities the transition to integrated intellectual solutions is planned.
What kind of development path should Russian cities take? The choice of an optimal digital transformation scenario depends to a large extent on the goals set by the city, as well as on the initial conditions for digital development and availability of funding.

Smart lighting technology has proven to be the most affordable technology for city administrations in the face of budget constraints. Due to wide use of energy service contracts (return of funds to the investor within 6-7 years due to savings on energy resources during subsequent operation) Smart lighting in one or another volume has been implemented or is planned in many cities of the Russian Federation. Implementation of Smart Lighting projects with simultaneous construction of infrastructure based on IoT networks and deployment of intelligent lighting control systems is the current stage of development [3]. Availability of infrastructure and intelligent lighting control system allows you to later connect additional networks (meters, environmental control, etc.), approaching the full Smart City.

The research objective was to study and summarize the experience of Smart Lighting projects in the cities of the Russian Federation.

2. Methods
As of February 2020, the Russian Federation does not have a single national standard in the field of smart cities, approved in accordance with the requirements of legislation. There are only departmental documents which are either completely basic or, on the contrary, concern individual decisions [4]. Therefore, the development and implementation of smart city projects in the Russian Federation, and thus smart lighting projects, have so far been carried out in accordance with existing international standards and international practice.

ISO 37120:2014 standard “Sustainable cities and communities. Indicators for city services and quality of life” was introduced in 2014. It identified 46 mandatory and 56 additional indicators in 17 areas. A standard identical to this one was issued in the Russian Federation in 2015 – GOST ISO 37120:2015 standard.

Using the standard helps to quantify the status of different directions of a smart city and identify areas of concern. Based on these assessments, cities strive to improve their position in the Word Council on City Data (WCCD) registry, which is responsible for ISO certification.

Since 2016, the International Telecommunication Union (ITU), with the support of the United Nations Economic Commission for Europe, has been certifying cities to the Smart Sustainable City Standard (U4SSC). Certification provides an assessment of 54 key and 37 additional indicators [5].

Since 2010, Moscow has been implementing a large-scale program for creating a smart city, and is a leader in this field in the Russian Federation. In 2019, Moscow, having submitted data on 76 indicators to experts, successfully achieved certification, received U4SSC certificate and became a sustainable smart city.

However, none of the listed international standards has specific indicators that would allow us to evaluate the energy efficiency of the urban exterior lighting system.

The first document in the Russian Federation, which included energy-efficient exterior lighting as one of the directions for implementing the concept of a smart city, was the departmental standard of the Ministry of Construction of the Russian Federation, 2019 [06]. And that makes sense, because the Ministry plans to develop areas within its competencies, primarily within the framework of the “Housing and Urban Environment” national project. Therefore, the list of directions implemented within the departmental standard is much shorter than the lists of international standards. Within the framework of the standard, it is suggested implementing 28 directions combined in 8 groups from 2019 to 2024.

The index of digitalization of municipal economy “City IQ” is developed by the Ministry of Construction of Russia together with Lomonosov Moscow State University as part of a departmental project called “Smart City.”
“City IQ” is calculated in ten areas (management, housing and public utilities, innovation, transport, public and environmental safety, tourism and services, social services, economy, communications network infrastructure) and contains 47 indicators [7].

In the area of “innovation”, two indicators are used to assess the intelligence of the exterior lighting system — the availability of energy efficient urban lighting and the proportion of lighting posts covered by smart lighting management systems.

In the first calculation of the “City IQ” the basic level of digitalization of urban economy as of the end of 2018 was determined. The second calculation (based on the results of 2019) will show the effectiveness of measures that were implemented by the cities in 2019 under the departmental project “Smart City”. Thus “City IQ” will allow to estimate annually a level of digitalization of the city economy and efficiency of implementation of “Smart City” solutions, to reveal promising directions of their further development.

In 2020, “Information Technologies. Smart City. Indicators” draft national standard became available for discussion. The standard proposes an indicator for assessing the energy efficiency of urban lighting that is “the share of street lighting managed by an intelligent control system” [8].

An intelligent control system is a management system capable of remotely monitoring light points, setting off/on schedules and adjusting light levels by dimming. This means that the light point can be individually and remotely controlled by an ICT-based system that is connected to the light points via a communication network. The system shall also measure the electricity consumed by the light point and report faults using ICT.

Thus, it is reasonable to assess the effectiveness of measures to improve the energy efficiency of public lighting, carried out by Russian Federation cities under the “Smart City” project, on two indicators:
- the availability of energy efficient public lighting;
- the share of street lighting controlled by an intelligent control system.

3. Results

According to the requirements of the standard terms of reference for the development of the Smart Lighting project (a project to improve the energy efficiency of the city's exterior lighting system), not only replacement of obsolete lights with new energy-saving ones, but also installation of an automated exterior lighting control system with fiscal electricity metering functions should be provided.

In addition, on the backbone of the lighting system under design, an individual control module must be installed together with each light to allow remote control of each light's power, both individually and as a group, via wireless data transmission channels, as well as to monitor the status of each light [3].

Modernization of the exterior lighting system in the city of Ivanovo (as of January 1, 2019, the population of 405 thousand people) was carried out in 2018 by Lighting Technologies ESCO LLC in cooperation with the national operator of information and communication services ER-Telecom Holding JSC with the support of the government of the Ivanovo Region.

More than 86% of the total number of street lights were replaced. 15.5 thousand modern LED lights were installed to replace outdated mercury and sodium lamps, of which 6.7 thousand lights were equipped with controllers and wireless access devices using LoRaWan technology [9].

The automated lighting control system was implemented on the basis of the existing wireless network IIoT (Industrial Internet of Things) of ER-Telecom Holding JSC built on LoRaWan technology and designed for digital transformation of production and urban infrastructure. The system control center was located in the building of the unified dispatching service of the city.

The control system allows remote control of both the power of each light equipped with a controller (dimming from 0 to 100%) and groups of lights. In addition, it provides remote online monitoring of a number of light parameters and control of its performance.

As a result of the modernization, electricity consumption decreased by 69% with a simultaneous 1.25 to 2-fold increase in lighting in the city streets (Fig. 1). Additional savings of up to 15% can be
achieved by dimming and selecting economical lighting scenarios [10]. The created network infrastructure can be used to further expand the list of Smart City technologies (metering devices, air pollution control, traffic management, etc.).

Modernization of the exterior lighting system in the city of Belgorod (as of January 1, 2019, the population of 392 thousand people) started in 2007 with installation in the pilot mode of “Helios”, the automated lighting control system developed by the Institute of High Technologies of Belgorod State University. The control system allowed, in addition to the usual monitoring of the state of networks, to keep records of power consumption and remotely control not only on/off, but also modes of operation, which was achieved through the single-phase switching of the power lines.

The use of “Helios” control system even without replacement of obsolete types of lights allowed to reduce energy consumption by 20 % during the first year of operation, and to reduce operation costs by 30 % [11].

Currently, as part of “Helios” automated lighting control system, depending on the needs and the project estimates, three functions can be implemented: light control, phase control and dimming.

The light control function is used for lighting cities, large industrial facilities, roads and highways. It provides for targeted control of each light, including dimming, with an option to group them. Adjustment of illumination level of the whole line is carried out through regulation of each light individually. It reduces power consumption (without changing lights) of up to 40 %.

Less flexible is the phase control function, which is used for upgrading of short networks in small communities and adjacent areas. It provides control of exterior lighting networks in single phase. The system makes it possible to set different switching schedules for each phase, lighting is switched on 100 %. It is possible to switch as scheduled, or with reference to the solar calendar. It provides a 30% reduction in power consumption.

The dimming function is used for lighting the adjacent areas of shopping malls, parking lots, warehouses. It provides for flexible change of lighting power modes (dimming) on individual lines. It provides a 40% reduction in power consumption.

The general scheme of control system operation is shown in Fig. 2 [12].
The device receives signals through communication channels PLC/GSM/RF/LoRaWAN and converts them into DALI/PWM interface signals / 0-10 V.

The “Helios” control system is wireless and is implemented on the basis of the ideology of application of the existing GSM communication networks using SMS messages. However, the exchange of information can also be organized through PLC/RF/LoRaWAN communication channels. As standard equipment, direct control of lights is carried out by the control cabinet through power lines, converting the signals received into interface signals of DALI/PWM/0-10 V (Fig. 3) [12].

**Figure 2.** General control system operation scheme

**Figure 3.** “Helios” control circuits

In 2010, the control system has been already servicing 24,000 lights, for the control of which 572 cabinets of the control system were installed. In 2020, there are more than 213 thousand lights in the
Belgorod Region, of which 65 % are controlled by “Helios” automated control system. Over the past 10 years, the number of lights in the region has increased by 113 %, but due to the introduction of an automated system and a reduction in the average capacity of one light, the annual energy consumption of the lighting system has increased only by 53 % [13].

4. Discussion
Existing international standards in the field of Smart City use generalized energy efficiency indicators of electric power networks, which makes it impossible to use them to evaluate Smart Lighting projects in the cities of the Russian Federation. To assess Smart Lighting projects, the indicators offered in the departmental standard of the Ministry of Construction of the Russian Federation, the “IQ Cities” index and the draft of the “Information Technologies. Smart City. Indicators” national standard are used.

To assess the energy efficiency of public lighting, it is advisable to use two indicators:
- the availability of energy efficient public lighting;
- the share of street lighting controlled by an intelligent control system.

For different types of Russian cities, in general, we can distinguish three models of digital transition [3], in which smart lighting projects are implemented:
- decentralized model for cities with more than 1 million inhabitants (primarily Moscow, St. Petersburg), where digital transformation is carried out with the participation of a large number of business players and in the context of significant market capacity for the implementation of smart city technologies;
- centralized model for large and medium-sized cities, where the process of digital transition is coordinated by local authorities, attracting available resources and necessary contractors;
- local action model for medium cities and small towns, in which due to lack of resources, individual, the most problematic infrastructure sectors of the urban economy are being transformed.

The study of experience in implementing smart lighting projects shows that the most popular model of transformation of exterior lighting systems is the model of local actions. The energy service contract is becoming a popular way to finance projects.

Exterior lighting upgrade projects usually start with launching pilot areas within several streets or neighborhoods while preparing the wireless IoT network infrastructure. In the future, the share of coverage of lighting networks is increasing.

Smart lighting systems, which provide a wide range of automated control functions from simple line dimming to light control are used more often. This allows reducing costs in project implementation through a smart combination of functions and gradual replacement of old lights with modern energy-efficient ones.

All projects use wireless networks to ensure information exchange between servers and control cabinets. There is a trend away from using wireless GSM networks and building specialized IoT networks (LoRaWAN). The created network infrastructure can be used to further expand the list of Smart City technologies (metering devices, air pollution control, traffic control, etc.).

5. Conclusions
To assess the energy efficiency of public lighting under “Smart Light” projects, it is advisable to use two indicators: the availability of an energy efficient network and the indicator “share of street lighting controlled by an intelligent control system”.

The transition to smart lighting in most of the projects being implemented is based on the local action model, in which only lighting networks, sometimes together with the construction of IoT wireless networks are being transformed in medium cities and small towns. The energy service contract is becoming a popular way to finance projects.

The most promising projects shall be recognized as those that implement functions of light control with the help of wireless networks.
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