International Journal of Latest Engineering Research and Applications (IJLERA) ISSN: 2455-7137

Volume – 09, Issue – 04, April 2024, PP – 01-10

A Study on the Standard Model of Smart Street Light

Jaemin Kim[1], Sangmuk Cho[2], Byunggoo Lee[2], Jinsheon Kim[2]

[1]*Joongmin, 18, Baumoe-ro 41-gil, Seocho-gu, Seoul 06741, Korea*

[2]*Lighting Equipment Center, Korea Conformity Laboratories, Incheon 21591, korea*

Abstract: Smart streetlights are innovative solutions that emphasize energy efficiency and environmental friendliness. Through the transition to LED lighting, they achieve energy savings and have the potential for efficient facility management. The development of smart streetlight systems requires interoperability, compatibility, scalability, and adaptability. A smart streetlight system integrating lighting control, remote monitoring, and environmental sensing capabilities is needed, and various configurations are compared considering laws and regulations. A survey of the application status of smart streetlights domestically and internationally reveals that they offer various services and functions such as energy savings, remote control, sensor integration, and smart city applications. Successful implementations of smart streetlights can be observed through case studies in domestic cities. The system configuration and functional analysis of smart streetlights explain the roles of IoT platforms, network infrastructure, and streetlight controllers, as well as key technologies such as sensor-based road condition detection, lighting control, wireless communication, and power supply management. The challenges and prospects of smart streetlights cover considerations such as standardization between products, technological stabilization, cost issues, patent rights, and maintenance. It emphasizes the need for collaboration between governments and businesses and a comprehensive approach. This research highlights the potential of smart streetlights and the importance of improving urban lighting infrastructure. It will be helpful in supporting the application and dissemination of smart streetlights.

Keywords: Smart Street Lighting; Dimming Control; Smart cities; Smart Lighting

1. INTRODUCTION

Since the third industrial revolution of the 20th century, the excessive use of fossil energy has polluted the earth's environment and destroyed ecosystems, greatly threatening the quality of human life.

Recently, with the declaration of eco-friendly policies such as greenhouse gas reduction and the implementation of environmental regulation systems such as RoHS (Restriction of Hazardous Substances Directive), energy saving and climate change have become a major issue, and interest in energy efficiency has increased significantly.

Global warming is a phenomenon in which the temperature rises due to the greenhouse effect caused by so-called greenhouse gases such as carbon dioxide, methane, and nitrous oxide emitted into the atmosphere due to human activities, and excessive human energy consumption is the main cause.

In particular, the lighting sector, which accounts for about 20% of total electricity consumption, is an industrial sector with a large energy-saving impact, and countries are focusing on promoting and distributing LED lighting, as it is expected to reduce electricity consumption significantly when replaced with LED lighting[1].

In line with this trend of demanding energy efficiency and eco-friendliness, high-efficiency LED lights are being actively introduced in road lighting, and countries around the world are implementing policies such as technology development, standardization development, and distribution and expansion at the national strategic level to preempt the market.

In Korea, we are in the process of replacing existing street light sources such as high-pressure sodium lamps, metal halide lamps, and ceramic metal halide lamps with LEDs, and about 2.7 million street lamps and 1.56 million security lamps have been installed in existing road lighting facilities nationwide, and we are in the process of replacing aging road lighting facilities with LEDs. Smart streetlights, which enable color temperature control, sensor linkage, and remote control by adding object recognition sensors and communication to LED light sources, are long-term facilities that integrate IoT and ICT technologies, and many advanced cities and companies are strategically building them to build smart cities [2].

In addition, to build a smart street lighting system that can save energy and provide efficient facility management and various citizen services in line with the trend of the Fourth Industrial Revolution, the Korea Energy Agency is promoting the notification of smart street lighting certification standards [3].

In major developed countries, smart street lighting technology and related platforms are being developed based on mid- to long-term plans to build smart cities, and in particular, Europe and the United States are

developing various smart devices such as smart sensors, smart environmental sensors, and intelligent CCTV to configure smart street lighting and developing software platforms to implement them [4].

The government is also promoting a multi-departmental R&D project under the theme of 'Smart road Lighting Platform Development and Demonstration Research' involving the Ministry of Land, Infrastructure, and Transport, Ministry of Science and ICT, Ministry of Trade, Industry and Energy, and Ministry of Public Administration and Security.

The project is jointly developed by four ministries with a budget of 26 billion won from 2019 to 2023 to contribute to reducing traffic accidents by providing various road environment information (accidents, congestion, icing, traffic volume, pedestrian routes, vehicle movement direction and speed, acceleration and deceleration, vehicle reversal, falling objects, potholes, etc.) to the public, rather than just illuminating the function of streetlights on the road.

This means that information and communication technology (ICT) technology is applied to road lighting such as streetlights to directly collect and judge dangerous situations on the road and provide information as a 'digital sign', or I2X stands for Intra to thing, which means wireless communication between infrastructure (such as roadside base stations) and things.

The goal is to use technology to provide information to nearby pedestrians and vehicles so that they can react immediately in the event of an unexpected situation in accident-prone areas such as crosswalks, intersections, and tunnels.

However, due to the different interpretations of smart streetlights by local governments and companies and the vagueness of the general concept, technical stabilization, compatibility between products, and protection of domestic lighting manufacturers through related businesses are necessary for the successful development and distribution of smart streetlights.

In addition, it is inevitable that the cost will increase due to the application of expensive smart function sensors, and it is difficult for companies other than the manufacturer to maintain due to the application of patent rights or specific technologies, causing delays in defect processing and increased maintenance costs.

Due to inconsistent design standards for smart street lights, technical responses to design difficulties and defects are not possible, and prior consultation with local governments has become indispensable when applying smart street lights.

The market for smart streetlights is also dominated by a small number of companies, making it difficult for latecomers to actively participate in the market and develop related technologies.

It is judged that it is possible to establish standardization of technical standards when there are multiple companies competing for the technology.

The lack of sufficient verification of new technologies, such as communication methods, durability of major components, compatibility and reliability of various sensors, and related patents and certificates, has led to insufficient problem-solving measures. In the case of multi-functional streetlights, electromagnetic interference between sensors or components requires the acquisition of related certifications (electromagnetic compatibility registration certification, broadcast communication equipment conformity certification), but no company has certifications for integrated products.

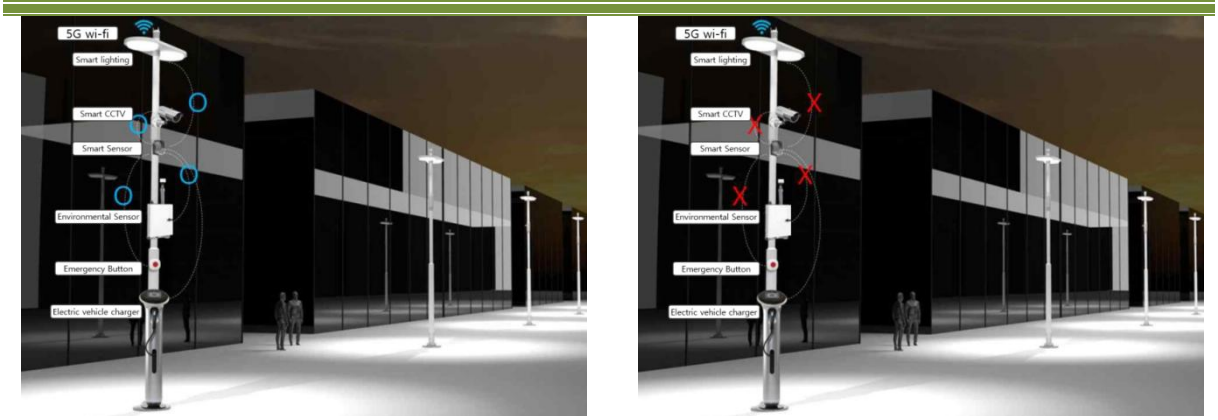
Therefore, given the lack of government guidelines and related technical standards, the diversification of services required by local governments and domestic smart street lighting companies, and the current trend of developing platforms rather than single items, a holistic approach and redefinition are needed.

In this study, we aim to prepare a standard model for smart streetlights through analyzing the current domestic and international application status and problems of smart streetlights, and analyzing technologies and institutions.

2. TECHNOLOGY AND INSTITUTIONS REQUIRED TO BUILD SMART STREET LIGHTING

Smart streetlights are a convergence solution of hardware and software that enables automatic operation, wired and wireless remote monitoring, and operation and management through smart devices based on existing road lighting facilities, and interoperability, compatibility, acceptability, and scalability are important characteristics.

- **Interoperability:** All LED light sources can be applied, and when configuring a smart street light, it is possible to operate in conjunction with disparate smart devices.
- **Compatibility:** Operability with disparate control software
- **Acceptability:** the ability to add devices or share new data.
- **Scalability:** the ability to operate in expanding geographies without replacing or adding hardware, with software development or adjustments



(a) (b)

Fig 1. Smart street light definition (interlocking, compatible, acceptable, scalable) Smart devices interlock and create new data through data sharing between smart devices at the same time as each data is generated, applying an integrated platform method (a); Smart street light definition inappropriate (classified as 1+1 concept) Smart devices attached to the main street lamp each generate data, but do not share data and create new data, requiring a separate platform (b).

2.1 TECHNOLOGY AND INSTITUTIONS REQUIRED TO BUILD SMART STREET LIGHTING

The smart streetlight system centers on lighting infrastructure and has a lighting control function that links external brightness based on remote control technology and a function to collect external environment (weather, air quality, noise, vibration, etc.) information using IoT-based smart sensors [5].

It can be used to provide civic urban services such as customized outdoor environmental information services and the establishment of public safety areas using location-based sensors (care, safety guardian, and loss prevention services), and to provide nighttime landscapes that are in harmony with nature by providing the right level of light at night.

- While the existing street lighting system is composed of independent operating systems for the single purpose of controlling lighting on and off, the smart lighting system is comprehensively integrated with various applications such as lighting, transportation, safety, life, and industry within the smart city main platform.
- It is based on interoperability of hardware and compatibility of software and is based on open protocols (API, OCF, M2M, etc.) based on the Internet of Things (IoT).
- It is a scalable system that can collect all irregular data such as traffic, weather, air pollution, noise, safety, parking, accidents, crime prevention, location tracking, and advertising, and works with various IoT devices.

Table 1. Comparison of features of smart streetlights and smart poles

Type	Multi Pole	Smart street lighting	Smart Pole
Hardware configuration	Operate multiple devices on a single pole	LED streetlights and smart control systems	Operate multiple devices on a single pole
Software	Device-specific control, monitoring, and operations management programs.	Remote control, monitoring, and operation management programs	Independent software API-linked integrated platform operation
Create Data	Create device-specific data	Facility assets, energy data, traffic data	Create new convergence data with each data algorithm

2.2. RESEARCH AND ANALYZE LAWS AND REGULATIONS RELATED TO SMART STREET LIGHT CONSTRUCTION

The straight part of the general part is divided into M1 through M5 by the driver's road lighting criteria.

The average road brightness Calibration Factor for each road lighting grade (M1 to M5) is classified from 0.5 to 2.0 as shown in the following table, and the height of the pillar and the arrangement distance of the street lamp are determined by this criterion [6].

(Road lighting standards for automobile traffic in Seoul: continuous lighting M3 road lighting grade applied)

Average road surface luminance of 1.0 to 1.4 (cd/m²), which is equivalent to an asphalt equivalent illuminance of 14.3 to 20 (lx).

Table 2. Driver road lighting standards

Type of road	Traffic Types and Car Bridges	Class
An intersection where the up and down lines are separated and the intersection is all three-dimensional; a high-speed road, motorway, or highway with completely restricted access.	In case of heavy traffic and complicated road alignment	M1
	In case of heavy traffic or complicated road alignment	M2
	When the traffic volume is low and the road alignment is simple, or when the surrounding environment is dark	M3
a highways, road separated by up and down lines	There is a lack of separation between traffic control and other forms of road users.	M1
	There is good separation between traffic control and other types of road users. There is a good separation between traffic control and other types of road users.	M2
Major urban transportation routes, arterials, and national highways	Lack of separation between traffic control and other types of road users	M2
	There is good separation between traffic control and other types of road users.	M3
Low-valued connecting roads, local connecting roads, main access roads in residential areas, and access roads and connecting roads to private property.	Lack of separation between traffic control and other types of road users	M4
	There is good separation between traffic control and other types of road users.	M5

Table 3. Roadway lighting luminance standards

Road Lighting Class	Average Luminance (minimum allowable) (Lavg), cd/m2	Luminance uniformity (The mineimum Allowable)		TI(%) (maximum Allowable)
		Total uniformity (Uo) Lmin/Lavg	Longitudinal uniformity (UI) Lmin/Lmax	
M1	2.0	0.4	0.7	10
M2	1.5	0.4	0.7	10
M3	1.0	0.4	0.5	15
M4	0.75	0.4	-	15
M5	0.5	0.4	-	15

2.3 APPLICATION STATUS AT KOREA AND ABROAD

Overseas, smart streetlights have been deployed in Copenhagen, Denmark; Barcelona, Spain; Eindhoven, The Netherlands; and Los Angeles, USA.

With the same international standards for street lights, ease of data acquisition, power supply and convenience of installing smart devices, fixed street light locations and reliability of data, smart street lights for smart city construction were applied first.

Table 4. Smart street light application service in overseas cities.

cities	main characteristics
Copenhagen[7]	LED, smart city technology, sensor, WI-FI, intelligent management, and providing the latest solutions Focus on smart indoor and outdoor lighting, smart city services, and biological effects of light Connecting street lights in the area using IoT technology
Barcelona[8]	Control the brightness of the lighting according to the number of floating populations by detecting the population density in real time

	Solve parking problems with smart parking service linked with smart street lights Form a powerful lighting sensor network with smart connected multi-sensor nodes
Eindhoven[9]	Plan to replace all public lighting with IoT artificial intelligence system Manage street lamp installation, lamp replacement and lighting time through individual street lamp history management Remote dimming function through smartphone app, appropriate dimming control according to weather
Los Angeles[10]	Philips adopts City Touch smart connected low-lighting management system Increase maintenance efficiency by automatically sending information of remote street lights to the manager 60% energy savings through LED replacement and scheduling control

In Korea, construction has been completed through smart street light demonstration complexes, pilot projects, and improvement projects such as Busan Metropolitan City, Gwangju Metropolitan City, Changwon City, and Sejong Special Self-Governing City.

Table 5. Smart street light application services in overseas cities

cities	**major cities**
Busan Metropolitan City	Buk-gu (MandeokStation~Hanshin Apartment) installed smart node integrated LED lighting fixtures on 107 street lights Remote control and illuminance sensor attached at the smart support center to control ON/OFF and dimming according to external brightness
Gwangju Metropolitan City	LED street light standardization and smart security light promotion Establishment of intelligent road lighting control system for dimming control using CDMA method
Changwon City	Establishment of public facility power control system based on ICT/IoT technology (July 2017) LED automatic lighting illuminance control system applied, LEMS technology applied
Sejong Special Self-Governing City	Automatic fault detection and email transmission of fault information for street lamp lighting Various lighting control settings that automatically limit the brightness of street lights according to road conditions

2.4 SYSTEM CONFIGURATION AND FUNCTION ANALYSIS

The smart street light system consists of an IoT platform, a network, and a street light controller [11-12].

(IoT platform) Manage data, provide web server web application, and provide convenience of management by remote control monitoring, failure and security management function

(Network) It consists of an IP network for connection with a computer or administrator and a Sensor or Node used for wireless local area communication.

(Street light controller) It consists of a sensor method that detects pedestrian or vehicle movement, a node method that specifies the communication method of smart streetlights, and a PLC method of self-programming.

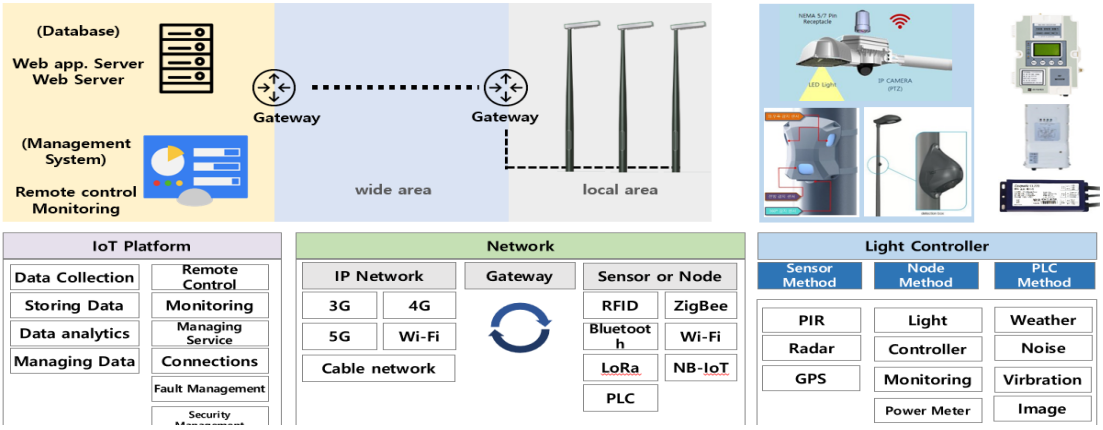


Fig 2. System components and supported functions of smart streetlights

Table 6. Components of a smart street lighting system and their roles

Category		Key Technologies
sensor	road condition detection	Object movement direction, speed, traffic volume, real-time detection sensor technology
	Failure and usage detection	Sensors that automatically detect power usage, operational status, and device failure causes
control	dimming control	Dynamic dimming control technology to adjust brightness by road section, time of day, and street light with basic dimming rate 1-10 level control
	Lighting Zone	Automatic control of the brightness of street lights according to the moving direction and speed of objects
	wireless communication	Short-distance and long-distance wireless communication control management technology
	power supply	Auxiliary power control operation technology when power is not supplied
wireless communication	Short-distance	Near-field control of data transmission and reception between streetlights, gateways
	long distance	Manage remote settings for sending and receiving data between gateways
remote control	Information analysis and control	Operation and traffic information analysis and monitoring technology

Additional services that can be provided to citizens through lighting infrastructure include intelligent CCTV, black box security lights, public Wi-Fi, electric vehicle (smart device) charging, outdoor environmental information, public safety zones, and green smart school zones[13].

Table 7. Additional Services Utilizing Lighting Infrastructure

Category	Key Features
Intelligent CCTV	Multiple CCTV Controllable CCTV Traffic, crime, incident, accident and natural disaster monitoring
black box security light	Real-time shooting and recording of surroundings Installation of accident and crime routes
public Wi-Fi	Providing communication welfare for the information marginalized class Wi-Fi AP installation on streetlight poles
Electric vehicle charging service	Electric vehicle slow charger installation Securing charging infrastructure based on lighting poles
Smart device charging service	Relieving citizens' inconvenience with battery charging Securing charging infrastructure using lighting power
Outdoor environment information service	Installing a Lighting-Connected Outdoor Environmental Sensor Leveraging environmental data collection across cities
Public safety zone service	Light pole fixed beacon installation Improving the accuracy of location information
smart crosswalk	LED floor signal by signal control, voice support Crosswalk floodlight control linked with traffic volume measurement sensor

3. PROPOSE A STANDARD MODEL FOR SMART STREETLIGHTS

We have created a standard model for the dimming control and fault management system that is the basis of smart streetlights. Additional services utilizing other lighting infrastructures are optionally added and used as needed.

3.1 SMART STREET LIGHT POLE

Smart land infrastructure with convergence of smart city technologies such as public Wi-Fi, intelligent CCTV, and smart crosswalks while performing the functions of road facilities (street lights, traffic lights, security lights, CCTV, etc.)

Establish smart city infrastructure by establishing smart pole technology standards that can be converged with smart city technologies on street lamp posts, which are urban infrastructure

Improve urban aesthetics and secure functions by integrating smart devices to implement various road facilities and urban services that hinder aesthetics.

Build future-oriented urban infrastructure by standardizing smart poles for systematic facilities of various road facilities and smart devices

Designated ZONE compartments for each device for efficient installation and management of various road facilities and smart devices on smart poles Smart pole standard design

- (Smart pole design) Design of various types of smart pole standard models that can easily add and replace smart devices and ensure structural stability
- (ZONE operation) Establishment of smart pole standards by providing clear standards such as smart device installation height, device capacity, and limit capacity through smart pole ZONE compartments
- (Piping and wiring) Piping and wiring are separated by purpose to prevent electrical and physical interference, and constant power for smart devices is added to reflect the design

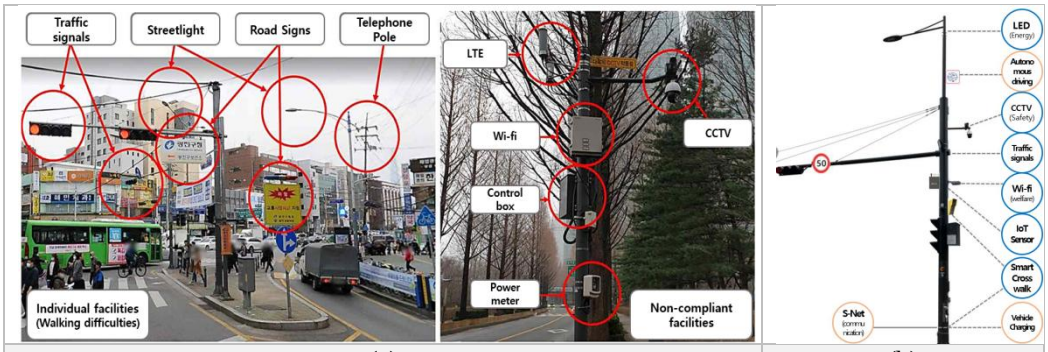


Figure 3. Difficult urban infrastructure before the application of smart streetlights Complex urban infrastructure before smart street light application (a), Improved city aesthetics after applying smart streetlights Improved city aesthetics after applying smart streetlights (b)

3.2 DIMMING CONTROL AND FAULT DIAGNOSIS SYSTEM DIMMING CONTROL AND FAULT DIAGNOSIS SYSTEM

It is a system that controls lighting and determines whether there is a failure in conjunction with sensors applied to smart poles.

According to the Ministry of Land, Infrastructure and Transport's 『Road Safety Facility Management Guidelines』, the dimming (dimming) control method according to traffic volume can be used depending on the type of lighting fixture, and the application functions are as follows.

- Lighting control by wired and wireless communications Surveillance of facilities and control of street lighting
- Contextualized lighting control with real-time vehicle or object detection
- Control systems for remote surveillance and control, data analytics, and remote monitoring
- (Scope of application) Places continuously installed with continuous lighting and large-scale local lighting
- Exclusion: Places with high risk of traffic accidents (intersections, crosswalks, railroad crossings, etc.)

(Control method) Dimming control methods based on time of day, traffic, etc. are available depending on the type of luminaire.

(Lighting level) You can dim the light 2 steps lower than the standard light level according to time and traffic, but you must secure at least M5 level or higher

(Dimming scenario) Based on continuous illumination for automobile traffic (CIE criteria) - (Roadway lighting rating parameters) divided into 8 categories: speed, traffic volume, traffic composition, lane separation, intersection density, parked vehicles, ambient luminance, visual guidance, and traffic control.

3.3 DIMMING SYSTEM STANDARDIZATION

1) System Overview

- The configuration of the dimming system shall satisfy the road lighting grade within the stopping distance based on the design speed of the road through the sensor device, controller, and gateway.
- It should be able to work with other smart sensors and enable real-time monitoring and fault detection through the operation management program.

2) Communication Protocol

- The gateway shall apply open protocols to enable data interworking with integrated platforms or homogeneous smart street lighting systems.

3) Sensor Devices

- Devices that detect vehicles on the road, such as radar, infrared, and light sensors.
- (Sensor-based) Sensing shaded areas due to vehicle progression shall not occur within the lighting section, and the sensing distance shall be at least 50m considering the maximum equidistant spacing of 40m

4) Illuminated section

- The forward illuminated section must be illuminated for at least as long as the stopping distance based on the design speed of the roadway [6].

Table 8. Stopping Time Criteria by Design Speed

Design Speed (km/h)	Stopping distance (m)	Design Speed (km/h)	Stopping distance (m)
120	280	60	85
100	200	50	65
80	140	40	45
70	110	30	30

5) Dimming Method

- Must be capable of dimming from a maximum of 100% to a minimum of 20% of the luminaire's total luminous flux using any dimming control method (DALI, PWM, 0-10V, 1-10V).

6) Dimming set value

- It is the time it takes to reach the maximum dimming from the minimum dimming, and the dimming time and brightness must be satisfied as shown in the table below to prevent unpleasantness due to sudden changes in brightness.

Table 9. Dimming setting criteria

Setting items	set value	Setting contents
Maximum light duration	30sec	Maintains full brightness for 30 seconds after vehicle detection, with duration increasing if additional vehicles are detected within 30 seconds, and Down dimming time applied if no vehicles are detected
Up Dimming Time (seconds)	2sec	Time to increase from set minimum brightness to maximum brightness
Down Dimming Time(seconds)	2sec	Time to decrease from set maximum brightness to minimum brightness
Dimming brightness	Road lighting Rating	Must meet a roadway lighting rating calculated based on traffic volume and speed. At least M5
Emergency return brightness	100%	In the event of a communication failure or malfunction, the luminaire should return to the set brightness

7) Communication

- Devices must send and receive commands and results to nearby devices and gateways via wireless communication (LoRa, Wi-Fi, BLE, RF, etc.)
- Execute and operate short-distance communication (LoRa, Wi-Fi, BLE, RF, etc.) with the controller

It shall perform functions that can operate and manage smart streetlights by executing programs and network communication.

8) Operation Management Program

- It should be possible to set the dimming behavior and method of the lighting control device, and establish a program that can detect faults and monitor the operating status through real-time wireless remote control with the controller.
- The operator can check the situation of emergency or failure, and can be operated automatically or manually according to the set value in the emergency situation.

9) Smart Sensor Integration

- When additional smart sensors such as CCTV and environmental sensors are added to the smart street light, the smart street light system should be operated in conjunction with the data from those sensors.

4. DISCUSSION

4.1 POWER MANAGEMENT OF SMART STREET LIGHTS

In order to build a smart city, it requires many advanced technologies such as ICT technology, communication, sensors, and networks, and the most basic and important stable power supply base that enables them to be organized.

When linking the 5G network construction promoted by the government with the smart city business, a stable power supply network is a prerequisite for the establishment of a communication network in as many locations as possible.

Therefore, as a preliminary project for the application of smart street lights and the construction of a smart city, it is very important to organize and confirm the guidelines related to the power supply of street lights in advance, which is recognized as a very important task that can determine the initial success or failure of the smart road lighting platform construction.

Since it is a "24-hour full-time power supply" condition that must be promoted for smart cities, a creative and positive method of performing work by the road lighting management department is required. The role of smart lighting for building a smart city is absolutely essential, and the importance of smart streetlight attention is gradually increasing, which is a global trend.

There are situations where there are concerns about safety accidents due to 24-hour power supply, but considering the 24-hour operation status of CCTVs, public Wi-Fi, and various sensors, which are rapidly increasing in recent years, appropriate construction and sufficient It's not a big deal if you manage it.

4.2 INTELLIGENT DIMMING SYSTEM BRIGHTNESS CHANGES

Road lighting reduction can be used on most roads, but it is not desirable to implement a dimming system in certain areas.

This particular area refers to areas where visibility is important, such as roads with many curves with short visibility or where traffic and pedestrian usage persists at night (ex. hospitals or other service facilities).

When a driver who was driving in bright light in daily life suddenly enters a dark road, it takes time to adapt.

- Depending on the luminance change threshold that determines whether extra acclimation time is needed, how abrupt the luminance change is, and the age of the driver, this transition can be uncomfortable and dangerous.
- Lighting levels should be varied at regular intervals, keeping in mind that darkening large areas without taking into account differences in night time road use may result in some areas being too dark.
- The dimming system should be applied after continuous monitoring of the road and the environment.
- To determine when narrow streets and residential and pedestrian paths can be generally darkened, it is important to take into account changes in traffic volumes of vehicles and pedestrians sampled over a period of time, closing times of surrounding commercial areas (malls), public transportation transit times, etc. to provide for citizen and resident needs.
- Dimming systems are also undesirable during inclement weather. Some studies have shown that driver visibility is negatively impacted by poor luminaire illumination when driving on wet roads during fog, snow, rain, etc.

5. CONCLUSION

Many local governments and companies are struggling to respond to smart streetlights and smart cities, which are currently trending internationally.

However, in the absence of relevant standards, different functions and requirements are being developed, which is becoming a problem for the national smart street lighting project.

In this study, a standard model for smart street lights was proposed to solve this problem. By defining the concept of smart street light and presenting standards for the most basic dimming system and maintenance system, it was intended to increase the accessibility of the smart street light business in related industries.

Details should be prepared through the enactment of related standards, but it aims to speed up the development of industries such as smart street lights by establishing the concept of smart street lights and collecting opinions from local governments, land and housing corporations, and related industries.

If future research is conducted on detailed standards such as communication protocols (open protocols and API integration), sensing distance of sensor devices, and adjustment of dimming settings, it will be possible to expand to smart cities based on standardized smart streetlights.

6. ACKNOWLEDGMENTS

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning(KETEP) grant funded by the Korea government(MOTIE) (Energy saving Smart Lighting Platform Technology Development and Demonstration" and task number " 20202020800220)

REFERENCES

[1] Costa, M. A. D.; Costa, G. H.; dos Santos, A. S.; Schuch, L.; Pinheiro, J. R. A High Efficiency Autonomous Street Lighting System Based on Solar Energy and LEDs. 2009 Brazilian Power Electronics Conference 2009, 265-273. DOI: 10.1109/COBEP.2009.5347688.

[2] Korea Land, Infrastructure and Transport Science and Technology Agency. Smart road lighting platform development and empirical research project planning report 2019.

[3] Ministry of Trade, Industry and Energy. "Regulations on the promotion of the supply of high efficiency energy equipment."

[4] Castro, M.; Jara, A. J.; Skarmeta, A. F. G. Smart Lighting Solutions for Smart Cities. 2013 27th International Conference on Advanced Information Networking and Applications Workshops 2013, 1374-1379. DOI: 10.1109/WAINA.2013.254.

[5] Sikder, A. K.; Acar, A.; Aksu, H.; Uluagac, A. S.; Akkaya, K.; Conti, M. IoT-enabled Smart Lighting Systems for Smart Cities. 2018 IEEE 8th Annual Computing and Communication Workshop and Conference (CCWC) 2018, 639-645.

[6] CIE 115 : 2010. LIGHTING OF ROADS FOR MOTOR AND PEDESTRIAN TRAFFIC 2010.

[7] Bjørner, T. The Advantages of and Barriers to Being Smart in a Smart City: The Perceptions of Project Managers within a Smart City Cluster Project in Greater Copenhagen. Cities 2021, 114, 103187. DOI: 10.1016/j.cities.2021.103187.

[8] Sanseverino, E. R.; Scaccianoce, G.; Vaccaro, V.; Zizzo, G.; Pennisi, S. Smart City and Public Lighting. 2015 IEEE 15th International Conference on Environment and Electrical Engineering (EEEIC) 2015, 665-670. DOI: 10.1109/EEEIC.2015.7165244.

[9] Sanseverino, E. R.; Scaccianoce, G.; Vaccaro, V.; Zizzo, G.; Pennisi, S. Smart City and Public Lighting. 2015 IEEE 15th International Conference on Environment and Electrical Engineering (EEEIC) 2015, 665-670. DOI: 10.1109/EEEIC.2015.7165244.

[10] Bachanek, K. H.; Tundys, B.; Wiśniewski, T.; Puzio, E.; Maroušková, A. Intelligent Street Lighting in a Smart City Concepts—A Direction to Energy Saving in Cities: An Overview and Case Study. Energies 2021, 14, 3018. DOI: 10.3390/en14113018.

[11] Leccese, F. Remote-Control System of High Efficiency and Intelligent Street Lighting Using a ZigBee Network of Devices and Sensors. IEEE Transactions on Power Delivery 2013, 28 (1), 21-28. DOI: 10.1109/TPWRD.2012.2212215.

[12] Elejoste, P.; Angulo, I.; Perallos, A.; Chertudi, A.; Zuazola, I. J. G.; Moreno, A.; Azpilicueta, L.; Astrain, J. J.; Falcone, F.; Villadangos, J. An Easy to Deploy Street Light Control System Based on Wireless Communication and LED Technology. Sensors 2013, 13, 6492-6523. DOI: 10.3390/s130506492.

[13] Walravens, N.; Ballon, P. Platform Business Models for Smart Cities: From Control and Value to Governance and Public Value. IEEE Communications Magazine 2013, 51 (6), 72-79. DOI: 10.1109/MCOM.2013.6525598.

