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A Study on Development Direction of Smart Pole for Smart City Construction

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Abstract

Smart pole is one of mega trend in smart city development. It has multi-function to get as much as data from the street to better city management. And smart street lighting of smart pole as core part of smart city development is being implemented by many cities in globally. Refer to the latest edition of Navigant Research's Smart City Tracker includes smart city projects in 221 cities, a quarter of which are deploying smart street lighting ranging from initial pilots to citywide and regional deployments that span tens and even hundreds of thousands of lights. The most important feature of smart street lighting solution is "Connectivity" through the IoT technology. In order to implement the smart city, we should have so-called intelligent watchdog and mesh networked post for keeping the various smart city technology development progress and operation properly. Smart street lighting solution could be main infrastructure as an enabler for a range of smart city applications. We can talk about the expected role of smart street lighting for the smart city development on this paper.

Keywords: Smart City, Smart Pole, Smart Street Lighting

1. Introduction

Recently, interest in smart cities has also increased due to social and economic issues such as urban development, population growth, environmental issues, and economic growth logic. However, the resulting national investment is being carried out around the world, somewhat independent of the nation's economic power. There has yet to be an accurate definition of smart cities around the world or an explicit resolution of the ultimate model of development. This is because it involves a complex and broad agenda beyond simple smart devices. In other words, Smart cities are customizable concepts optimized for the city through the organic and chemical combination of many city components, including culture, history, environment, economy, geography, and citizens[1,2].

Finding a core application or common infrastructure that can be applied equally to any city in the world is a way to promoting the development of smart cities and creating additional economic effects.

In this paper, data collection and trend analysis were conducted on the main policy of smart street lightings in the United States, Europe and Asia. Through this, we will be able to identify the direction of development of Smart Pole and prepare for it.

The composition of this paper is as follows. In Chapter 2, the concept of smart street lighting, related technologies and major policies are reviewed. Finally, Chapter 3 describes the conclusion of the study.

2. Main Body

2.1 The Concept of Smart Street Lighting

Smart street lighting is a hardware and software convergence system that minimizes the dependence of managers, information sharing among systems, and light environment suitable for the time and place where road lighting is needed, with the Internet and smart sensor-based artificial intelligent two-way wireless lighting control system.

The smart street lighting systems can be divided into four stages according to technological progress. Table 1 shows the technical steps of the smart street lighting

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Table 1. Technology level of smart street lightings

Type	1st level	2nd level	3rd level	4th level
Main Technology	One plus One	Remote Control	IoT	AI
Ref. Case	LED+CCTV in a Housing	Step Dimming and Monitoring	On Demand Light and Connectivity	Full Autonomous
Level of Technology	Not Applicable	Done and Progress	Evolving	Not Available

system. The first stage is not within the category of smart street lightings and the fourth stage is difficult to realize yet. Therefore, this paper focuses on the third stage Internet of Things technology.

2.2 Smart Street Lighting System

There are now 304 million street lightings worldwide and will increase to 352 million by 2025. The street lighting market is replacing the existing street lightings with high efficiency LED or semiconductor lighting technology, and LED street lightings are being networked to become smart street lightings while taking new steps with new technology.

In the report "Global LED and Smart Street Lighting: Market Forecast (2018-2027)" published by Northeast Group, global LED and street lighting markets were analyzed and predicted by 2027[3].

From 2018 to 2027, the LED street lighting market is expected to reach $ 57.8 billion, with countries expected to invest $ 53.7 billion. LED street lightings will change cities and municipalities over the next decade. Compared to conventional street lighting technology, LEDs have the advantage of long life, low energy consumption, and reduced maintenance costs. However, LEDs are not the only alternative to modernized public lighting. Networked smart street lightings help to reduce overall costs further by lowering lighting and reducing spending required to maintain when usage is low. As the cost of networkable street lightings sharply decreases, the role of smart street lightings in cities and municipalities around the world is likely to grow.

In most developed countries, telecommunications networks will be part of a smart city that connects electricity and water meters, street lightings, traffic lightings and parking meters, and smart street lightings can greatly improve safety by reducing the failure time of street lightings. As soon as the street lighting goes out, it is extremely unlikely that the lightings will be turned off on the street as the management staff receives the information. Especially in the cities of emerging nations that need to manage increasing street crime.

Overall, the future of LED smart street lightings is bright, but there are some challenges to overcome. For example, the price of LEDs should be continuously lowered and not standardized. Especially for network-connected street lightings, established standards in the United States will limit the company's ability to meet growing demand worldwide.

The Northeast Group's recent assessment of more than 800 LED and smart street lighting projects in 90 countries shows that cities and municipalities around the world have the same view of the benefits of LED and smart street lightings. Considering these advantages, LED and smart streetlights are expected to account for 84% and 37% respectively in the entire street lighting market by 2027. Also, the total market will reach $63.5 billion in cumulative value.

2.2.1 Existing Street Lighting System

The purpose of the street lightings is to provide a quick and comfortable visual environment for drivers and pedestrians on dark roads and sidewalks, and to reduce accidents, crime prevention and traffic accidents. The street lighting system consists of three elements, as shown in the conceptual diagram of the existing street lighting system in Fig. 1, such as a distribution box, a street lighting, and a control server.

Because the street lighting distribution box and the street lightings are distributed in a wide area, the man-

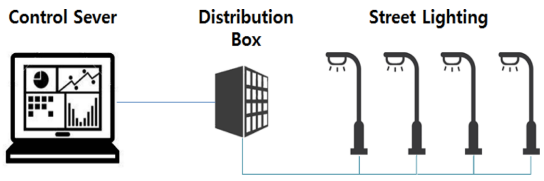

Fig. 1. Concept diagram of existing street lighting system.

ager cannot grasp the situation of each distribution box or street lighting in real time and cope with it.

Since the street lighting distribution box controllers use the built-in communication modem for communication with the control server, they cannot use the communication method other than the developed communication method, so they are developing according to the products[4].

In the operation and management of street lightings, the existing system is mainly comprised of systems using a one-way communication method that collectively turns on and off using Frequency Modulation (FM) frequency transmission, so that the status of the street lightings cannot be monitored in real time, and the manager can only identify the situation by patrols or civil servants, and there are problems such as too many administrative expenses and civil complaints after the accident. Therefore, the existing system is not able to manage efficiently due to the increase of manual operation and management street lights and the increase of inefficiency due to unnecessary factors, causing waste of energy and the inability to respond quickly due to manual operation[5,6].

To address this problem, studies are being conducted on street lighting systems that can be monitored in real time using two-way communication networks[7].

2.2.2 Street Lighting Remote Control and Monitoring System

In order to save energy, there is generally a method of adjusting the dimming value or controlling the dimming of the illumination. Conventional LED street lighting remote control and monitoring systems use Power Line Communication (PLC), which is a wire control method. The PLC method has problems such as noise, frequency interference, and carrier signals that often cause communication failures. This method of wireline is expensive to install, complicated, and has limitations in controlling and maintaining streetlights installed throughout the city. For this reason, a study on street lighting remote control and monitoring system using wireless sensor network was conducted, and there is also a radio control method using RF technology [8].

Sensor nodes communicate wirelessly using different Industrial Scientific Medical (ISM) bands. Sensor nodes are located in one group and all groups have sink nodes that work for the sensor nodes, which serve to connect to remote user computers using an Internet Protocol (IP) network. Applications running on the computer are used to control and monitor the street lighting system to ensure real-time monitoring and immediate detection and rapid recovery in the event of street lighting failure.

In addition, the results of comparing the advantages

Table 2. Advantage and disadvantages of PLC and WSN

Power Line Communication (PLC)	
Advantages	▪There are no obstacles in the communication path. ▪No additional wiring or signal repeater installation is required. ▪PLC is not affected by radio interference.
Disadvantages	▪It is more expensive than WSN. ▪The input and output ports that are not utilized due to their modularity are wasted. ▪It is vulnerable to noise, and there is a high possibility of data loss during transmission through a transformer. ▪The number of nodes that can be connected is small. (Less than 70) ▪Limited Communication Distance (300-350m).
Wireless Sensor Network (WSN)	
Advantages	▪It is cheaper than PLC technology. ▪Highly scalable control and maintenance through highly efficient sink node apps and networks. ▪Connection of many nodes and multiple communication paths are possible.
Disadvantages	▪The communication path depends on the environment. ▪Additional repeater installations are required to overcome obstacles. ▪The WSN is affected by radio interference.

and disadvantages of the PLC method and the wireless sensor network, which are wired for each lighting control and monitoring as a wireless network basis, are shown in Table 2.

2.3 Smart City and Smart Street Lighting

Of the 221 cities that build smart cities around the world, 25 percent have smart street lightings as their initial projects. This means that in order to build a smart city, the implementation of the city's smart street lighting system is a prerequisite for smart city implementation. Senior officials and related experts recognize smart street lightings as the first task of building smart cities. In addition, market research institutes predict that 73 million street lightings will be replaced by smart street lightings by 2026.

2.4 Infrastructure Technology for Smart Street Lighting Connectivity

The ultimate step in the technology of smart street lightings is to provide a light environment optimized for unspecified and irregular road conditions by a street lighting system equipped with artificial intelligence. It also aims to implement continuous decision-making capabilities through real-time networking and deep learning, as well as various smart devices such as autonomous vehicles, crime prevention, personal need information, and the protection system for the elderly and the elderly, all possible situations and optimal responses.

The first stage of evolution to this artificial intelligence (AI) street lighting system can be implemented around Connectivity.

The underlying technologies for connectivity include the functional development of semiconductor lighting LEDs, the extension of power supply functions, API interworking between sensor control period and the flexibility and compatibility of 5G and smart platforms for real-time large information sharing.

2.5 Interoperability, Compatibility, Scalability and Renewable Energy

The most basic essential requirements of smart street lightings are interoperability between major devices, heterogeneous hardware, software and compatibility, and scalability that can be extended without additional technology investment. The latest addition is to actively apply the Internet of Things as a technology for revitalizing renewable energy.

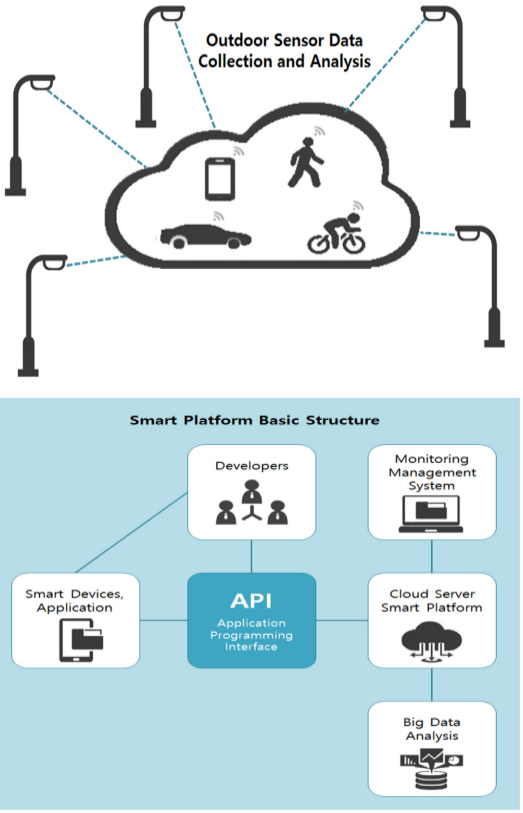

Fig. 2. Concept diagram of smart street lighting.

Examples include applying IoT system to existing solar street lighting systems, optimal charge and discharge control, non-uniform prediction and response, and implementation of fault life zero energy smart solar street lighting through wireless remote monitoring management.

Fig. 2 shows a concept diagram of a smart street lighting.

2.6 Major Policies of Overseas Smart Street Lighting

Under the theme of lighting engineering and lighting application engineering, the United Nations (UN) promoted sustainable R&D and emphasized the importance of global solutions for energy, education, agriculture and health. A large consortium of UNESCO and scientific organizations has led the topic and can be seen leading the lighting industry in various ways in various countries.

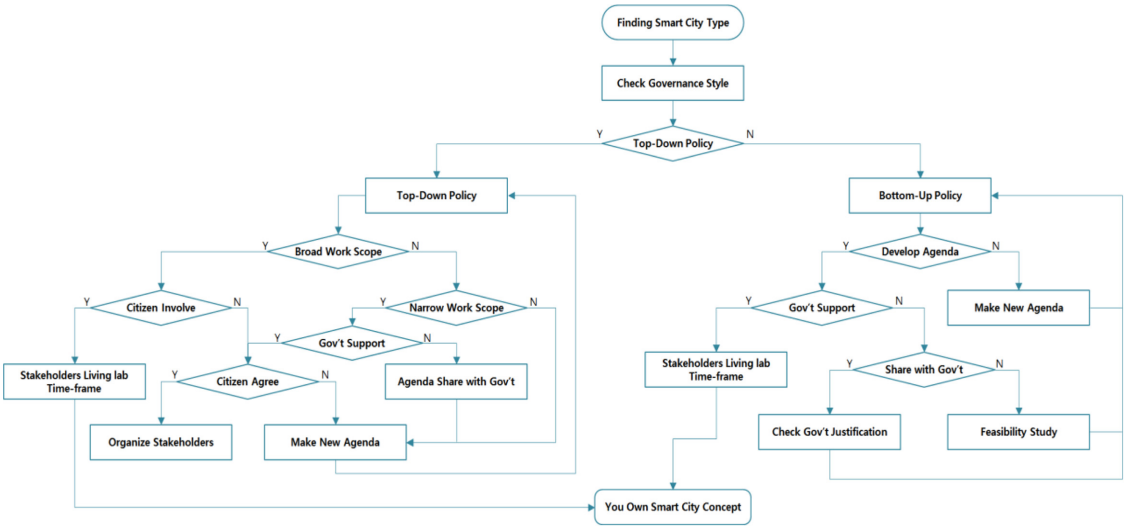

Fig. 3. Smart city concept according to the characteristics of each city building methods.

The way in which countries and consortium build smart city concepts depends on the characteristics of cities. The concept of a smart city that fits the concept of a city will be determined by dividing the top-down policy and the bottom-up policy into the bottom-up policy and the specific mode of progress. Therefore, we identified how smart cities are being implemented in Europe, the U.S., and Asia, and how smart streetlights are being implemented.

Fig. 3 shows how smart city concept is built according to city characteristics.

2.6.1 Eindhoven, Netherlands

The city of Eindhoven in the Netherlands is pushing for Roadmap Urban Lighting 2030 based on its vision of being a "smart city that can sustainably."

Through this project, five pilot project zones have been constructed for public lighting in cities since fall of 2016 and connected LED street lightings have been promoted as the main project for smart city construction.

2.6.2 Hampshire, United Kingdom

The city of Hampshire in the U.K attaches a road surface temperature sensor to the basic function of the smart street light and predicts the freezing of the road based on weather information (snow or precipitation).

It is applied with IoT sensor technology and infrared sensor technology and operates as a cloud method that enables real-time information sharing.

2.6.3 Los Angeles, U.S.

The city of Los Angeles in the U.S. replaced 110,000 of its 216,500 street lightings from 2016 to 2016 with smart street lightings, while the rest of the street lightings are also being replaced sequentially.

In 2017, the city of Los Angeles established 100 smart lighthouses (Smart Pole, Wireless Telephone Relay, Public Wi-Fi, Speakers, Electric Vehicle Charging, Emergency Beacons, etc.) and plans to install 500 units more by 2020.

2.6.4 Jakarta, Indonesia

The city of Jakarta has announced that the construction of smart street lightings is the most important and essential process for the development of smart cities, and is pushing for the expansion of 90,000 street lightings into other cities by replacing them with smart street lightings in 2016.

All smart street lightings are a two-way remote control and management system that allows real-time management and analysis of automatic lighting and dimming, street lighting conditions, and energy usage.

2.6.5 Singapore

As part of Singapore's Smart Nation Initiative, Sin-

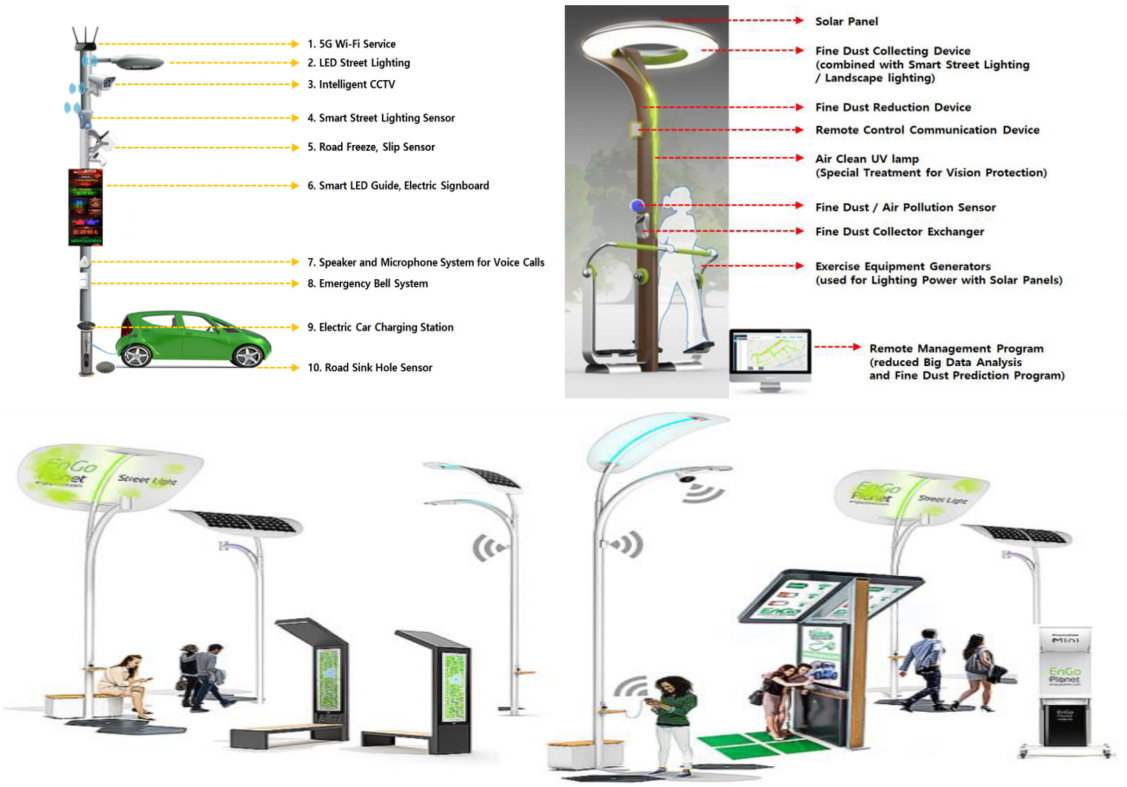

Fig. 4. The case of smart pole (Source: Ecorant Co., Ltd.).

gapore's Land Transport Authority (LTA) has set up 4,000 LED street lightings, 25,000 LED lights by 2019, and 20,000 LED street lightings as shared network for low bandwidth based on wireless sensors and Remote Control and Monitoring System (RCMS).

▪ Urban Lighting Policy

1) Revitalizing the Urban Landscape Lighting Project for the continued development of Singapore's tourism industry

2) Asia's Best Living City and World's Most Sustainable Development City Regeneration

3) Maintaining the highest quality in design, construction and maintenance through transparent international bidding

▪ Public Lighting Policy

1) Implement all street lighting smart solutions by 2022

2) Innovative energy savings (at least 25% reduction)

3) Construction of the newest remote control and monitoring system

4) Various technology convergence infrastructure to build Smart Nation

2.6.6 Abu Dhabi, United Arab Emirates

The city of Abu Dhabi of the United Arab Emirates is the first project among all street lightings, and 42,000 street lightings are being carried out in international bidding (May 2018) based on sensors and remote management systems, and construction is expected to be completed by June 2019.

In addition, plans for the annual smart street lighting project for the remaining 120,000 street lightings were also announced.

As shown in Fig. 4, the case of smart poles requires realistic technologies for the safety and development of cities.

2.6.7 Other Smart Pole Installation Operating Cites

Table 3 shows the cities where other smart poles are installed and operated.

Table 3. Other smart pole operating cities

Country	City	Contents
Spain	Barcelona	As a leading city in the construction of smart street lightings, the construction of smart city facilities for environmental monitoring functions such as dimming, humidity and air pollution using various sensor and radio communication technologies
China	Shanghai	The purpose of integrated maintenance of urban needs is to smarten existing equities such as CCTV, touchscreen, Wi-Fi, electric vehicle charging, emergency bell service, etc. on street lightings.
Netherlands	Neuenen	The purpose of the project is to reduce energy consumption, reduce maintenance costs and prevent crimes through dimming operation, which is automatic when roads are used based on smart sensors
	Tilburg	In 2010, the first case of saving energy and maintenance costs based on two-way remote radio communication and dimming functions was the case in which the initial smart street lightings was constructed.
Denmark	Copenhagen	Construction of two-way radio communication, automatic ignition and lighting, and Smart Road with dimming and photovoltaic renewable energy technologies under the head of the Denmark Outdoor Lighting Lab (DOLL) in 2014
USA	New York	The role of information sharing device that provides information by linking various information needed in the city with smart phone such as measurement and analysis of traffic congestion on smart street lighting
	San Diego	It is composed of the concept of smart light that supports firearms, air pollution, public Wi-Fi, and smart parking service in light dimming technology of smart street lighting
Portugal	Porto	By combining new renewable energy technologies such as solar energy and wind power with technologies such as smart green street lightings without power by constructing zero energy smart street lightings
Finland	JYVÄSKYLÄ	In order to minimize government budget and improve the light environment as part of smart city construction, smart street lighting and two-way wireless management programs are introduced.
Belgium	Wavre	Based on practical contents such as energy reduction, maintenance cost reduction, CO2 generation reduction, and light pollution reduction, various settings are implemented depending on the road conditions in operation.

3. Conclusions

In the next five years, smart poles will play a role as a blood vessel that connects the circulation of human organs and tissues to the heart of a large structure called the city, such as energy reduction, climate change response, events that may or may occur in the city, application of new technologies, and big data analysis, beyond the infrastructure for urban safety.

This will require innovative and continuous development of relevant direct and indirect technologies for smart street lightings.

Acknowledgments

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