
| RESEARCH ARTICLE

Case Study on Intelligent Road Lighting in Foreign Countries under the Background of Smart City

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| ABSTRACT

With the development of the city, the relationship between the city and wisdom has become more and more close. In this process, the attention of smart lighting construction has gradually increased, and many cities regard smart lighting as a promotion point for building smart cities. This paper adopts a qualitative research method to explore the typical road smart lighting construction cases in some foreign cities. By analyzing the cases of developing urban smart lighting construction in various countries, it is found that the functions of the transformed smart lighting can play an important role in energy saving, urban security, data collection, and citizen services for cities in various countries. Finally, by further summarizing the main content of its construction, it provides some reference suggestions for the development of smart lighting in my country.

| KEYWORDS

Smart City; Smart Lighting; Road Lighting

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1. Introduction

In recent years, the creation of smart cities has become a new trend in urban construction and development. Our country keeps pace with the times and incorporates it into the task of modern urban construction. For the construction of a smart city, a large number of hardware facilities are needed as the support point of its construction. As an important public infrastructure in urban construction, urban public lighting has an important impact on people's daily activities (F. & A., 2021). In the current modern urban construction, traditional urban lighting is no longer suitable for the development needs of modern urban construction. Smart city construction puts forward new development requirements for urban public lighting. Smart lighting with multiple functions has become a new goal of urban public lighting construction (V, Arudra, M, K, & Pallavi, 2021). In the road lighting system, urban street lights are important hardware facilities. With the combination of street lights and intelligence, it has developed from initially meeting the lighting function requirements of people's travel activities at night to today's integration of energy-saving lighting, video surveillance, audio, people flow testing, 5G, electronic screen information release, WIFI, environmental monitoring, Single lamp monitoring, electric vehicle charging pile and many other functions are integrated into one (Brazil, 2016).

The construction of foreign smart cities is earlier than that of my country, and some practical results have been achieved in the development of smart lighting. My country's smart lighting is still in the initial stage of construction, and there are a lot of problems at this stage. This article attempts to explore the practical overview of urban road smart lighting cases in some foreign countries, and provide some reference suggestions for the construction of smart lighting in my country.

2. Literature Review

Infrastructure construction has been basically completed for some developed countries such as the United States, Singapore, and the United Kingdom. Most of the urban road lighting facilities are mainly traditional lighting facilities with a single function and large power consumption, which cannot meet the development needs of smart cities (Mohandas, Dhanaraj, & Gao, 2019). In recent years, smart lighting has gradually become the key direction of urban construction in the construction of its city. As a

hardware facility in the urban road lighting system, urban street lamps have begun to transform traditional urban street lamps as the starting point for the construction of smart lighting in many developed countries.

In the development of smart road lighting in some of its cities, the construction of urban smart lighting is realized by using street lamps distributed in all corners of the city as connection points. The installed communication module sensor, combined with the wireless network, realizes the unified management of street lamps. At the same time, the management and control system of smart lighting can adjust the light intensity and switching time of street lights according to the light intensity and traffic flow, which saves a lot of power energy and later maintenance costs, and improves the city's overall public lighting management level and energy utilization rate(K, S, G, M, & M, 2018). In addition, the functions of people's livelihood information such as voice broadcasting, alarming for help, and electronic information release have been gradually developed and used, realizing data collection and sharing .

3. Research Object and Method

3.1 Research methods and object selection

This study adopts a qualitative research method and selects thirteen foreign cases of road smart lighting in different cities for exploration and analysis, including the United States, Singapore, the United Kingdom, France, Germany, Sweden, Australia, Denmark, Spain, the Netherlands, and Canada. In this case, the cities mainly rely on the renovation of streetlamps as the basis for the construction of urban smart lighting and combine the "light, network, cloud" comprehensive Internet of Things model for systematic management. Among them, in Los Angeles and Barcelona, the construction of smart lighting has promoted energy conservation and environmental protection in the city; in Copenhagen, the traffic data collected by sensor devices has effectively alleviated the city's traffic congestion; in Paris, the design of humanized street lamps has facilitated the daily life of citizens; Stockholm, public management platform to optimize urban lighting performance; Amsterdam, using new lighting materials; Brisbane, using clean energy for energy-saving lighting, etc..

3.2 Practice overview of the research object

Through the summary of road smart lighting cases in thirteen different foreign cities (Table 1), the construction achievements of each city in smart lighting are summarized, and the results are analyzed as follows. (1) The construction of urban smart lighting takes urban public infrastructure as the "foothold" (2) After the renovation of street lamps, it has multiple functions to serve the city (3) The effects created by the development of smart lighting can bring a lot of convenience to cities and residents (4) The main participants in the construction of urban smart lighting

Table .1 Overview of road intelligent lighting cases

City/ Country	Construction Content	participants	Practical points	
			Function	Effect
Los Angeles	Install the Philips Smart pole	Philips, Ericsson	energy saving lighting	1. Save approximately \$9 million in electricity bills and provide daily operation for approximately 100 electric vehicle charging stations 2.Reduce the city's carbon dioxide emissions by nearly 60,000 tons 3. The color of the street light can be converted from yellow to white to increase the comfort of the human body 4. In an emergency, the street lights will strobe to remind passing pedestrians, with the function of guiding the road 5.Realize real-time vehicle detection: When encountering a collision event, directly send
			WIFI	

			GPS	<p>information to the urban emergency communication system, shorten the time for relevant departments to arrive at the accident site, and improve rescue efficiency</p> <p>6. Realize single-level control: the street lights are connected to the local network and managed by the integrated platform system</p> <p>7. It has the function of signal receiving and transmitting tower: strengthen the signal, expand the signal range and disperse the communication load in the area</p>
			Acoustic and Noise Detection Sensors	
Stockholm	Install smart street lights and establish a management system	Swedish Urban Transport Agency	energy saving lighting	<p>1. Use the smart city management platform to optimize the control and management of street lamps and promote the efficient use of energy</p>
			connection management system	<p>2. Street lamp renovation and management system construction have achieved the city's sustainable goals and laid the foundation for building a smart city</p>
Copenhagen	Install the smart chip	Government public sector, private enterprises, research institutions	energy saving lighting	<p>1. Street lights have high color rendering, reducing electricity costs and carbon dioxide emissions by 65% in area</p> <p>2. Street lights can be automatically dimmed according to road conditions and traffic flow to promote urban energy-saving and driving safety</p>
			Intelligent detection control	<p>3. Sensors can collect information on road conditions and traffic flow, which can be transmitted to the road management system in time to adjust traffic signals, effectively improving the traffic efficiency of cyclists (if the public can maintain a speed of 20 kilometers per hour, they can go all the way under the uninterrupted green light)</p>
			Sensing equipment	<p>unblocked)</p>

Singapore	Upgrading urban street lights	Itron, China Rongwen Energy Technology, Singapore Ministry of Science and Technology and Ministry of Transport	energy saving lighting Sensing equipment communication network connection management system	<p>1. "On-demand lighting": improve operational efficiency, reduce energy consumption and post-maintenance costs</p> <p>2. Sensors collect urban data: water level, water flow, temperature, and humidity, etc., and can be transmitted to relevant public institutions in the city to improve work efficiency</p> <p>3. Through the transformation and upgrading of street lamps, the network will promote the construction of urban shared infrastructure</p> <p>4. Street lights are connected to the communication network, and the control of street lights is more stable and reliable, creating conditions for the city's urban planning and deployment in the next 10 years</p>
Barcelona	Install multi-functional smart street lights and improve the central smart control system	Barcelona government, Cisco, Google	Sensing equipment energy saving lighting connection management system	<p>1. Street lights have the functions of monitoring noise, traffic, pollution, etc.</p> <p>2. Install a small black box for receiving signals on the street lights to help the blind cross the road safely</p> <p>3. Street lights are mainly powered by solar energy (the lamp posts are equipped with photovoltaic panels and batteries, which can meet the lighting needs of six nights when fully charged), reducing electricity consumption by 60% and reducing municipal energy expenses by one-third</p> <p>4. The street lights are automatically managed by the central intelligent control system: the switch and brightness can be adjusted according to the season, weather factors, and distance from pedestrians</p>

London	Retrofit lights	street	City of London, Westminster Borough	energy saving lighting	connection management system	The turn-on, brightness, repair, and replacement of street lights are controlled by the iPad app, and reminder notifications can be sent to municipal engineers, reducing maintenance costs and promoting energy conservation in the city, saving approximately £420,000 in electricity bills per year		
Paris	Create convenient street lights		Paris government department, mathieu lehanneur (French industrial designer)	energy saving lighting	WIFI	seat	charge the phone	<ol style="list-style-type: none"> 1. The dome of the street lamp is made of aluminum material, and the direct downward divergent irradiation method can reduce light pollution and improve the utilization rate of electric energy 2. Part of the electricity is supplied by solar energy (solar panels are installed on the other side of the vault), which can provide about 3 hours of electricity for night lighting 3. The combination of WIFI, seat, and charging, sitting under the lamp to charge and connect to WIFI, is loved by the local people
Las Vegas	Using smart light poles	smart	Las Vegas Government, EnGoPLANET Corporation	energy saving lighting	WIFI	charge the phone	Sensing equipment	<ol style="list-style-type: none"> 1. Reduce carbon dioxide emissions and reduce maintenance costs 2. Provide free WIFI, USB mobile phone charging port, and seat 3. There are various ways to provide power for street lights: grid, solar energy, and pedestrians walking and stepping on charging (pedals are installed on the street lights, the pedals generate electricity according to pedestrians walking and stepping, each step can generate 7W of electricity, and the electricity is stored in batteries to supply street lights)
Milton Keynes	Multifunctional street lights installed around MK Stadium		Schreider Company, MK Dons Football Club	energy saving lighting				1. Shuffle equipment is installed at the ticket office and store entrance. The equipment has 360-degree lighting modules

				Surveillance cameras	(16 LEDs), CCTV, public address, and WIFI functions. The main control room of the stadium is connected to the public address and CCTV and can be remotely controlled. Play events and broadcasts
				public broadcasting	2. LED technology and control system, energy-saving, and high efficiency reduce maintenance costs
				WIFI	3. Using environmentally friendly materials, interactive mode lighting control system: "lighting on demand"
				connection management system	4. Surveillance camera: monitor the occurrence of dangerous situations in the relevant area
Berlin	Retrofitting street light poles	Berlin government, ubitricity company		illumination	1. The renovation of street lamp charging piles reduces the cost by about 90% (including renovation costs) 2. The technology is cheap, convenient, space-saving, and can be used to charge electric vehicles in more public places 3. The process from charging to paying for street lights only takes 3 steps and supports any electric vehicle to be charged on the same public charging pile, improving residents' interest in using it
				charging electric vehicles	
Brisbane	Building a Solar Pedestrian Bridge	Brisbane City Council, Cox Architects		energy saving lighting	1. Build a light-emitting diode (LED) lighting system (84 solar cells provide power for the LED light array), with an average annual output of 38,000 kWh, which can meet the lighting needs of the flyover 2. It will reduce carbon dioxide emissions by 37.8 tons per year
Amsterdam	Building Smart Lighting Highways	Daan Roosegaarde (artist), Heijmans (Dutch construction company)		energy saving lighting	1. The specific sections of the N329 highway are painted with Glowing Lines luminous paint material: the sunlight absorbed throughout the day can provide power and lighting for 10 hours at night 2. Install energy-saving lamps, which can gradually increase the brightness as the vehicle approaches, and turn off after

Montreal	Intelligent LED street light and intelligent lighting management system	City of Montreal, Quebec business	Intelligent detection control	the vehicle passes. 3. Road signs can be displayed continuously or intermittently according to different situations
			energy saving lighting	1. Replacing street lamps with LEDs can extend the life of lamps and save 60% of energy consumption and 55% of maintenance costs in area 2. The intelligent lighting management system can measure energy consumption in real-time, and can adjust the light intensity according to weather conditions or traffic flow, etc., and can also give timely reminders when street lights are faulty or damaged
			Intelligent detection control	3. Improve the perception of street light color and contrast, which can improve the vision for users on different roads. Among them, the street lights near parks and environmental public welfare areas have a warm color temperature of 1800K, which achieves the effect of "not disrupting the circadian rhythm of animals"
			connection management system	

Data source: Author collated according to relevant literature

Through the construction of smart lighting, the cities in the above countries have enabled their urban street lights to have other functions in addition to lighting. By further sorting out the smart lighting functions of cities in various countries (Table 2), its main functions are concentrated in four aspects: energy-saving lighting, sensor equipment, wireless network, and management system. At the same time, the practical effects of various functions of smart lighting (Figure 1) play an important role in energy saving, urban safety, data collection, and citizen services for cities around the world.

Table .2 Function statistics of intelligent lighting

City/ Country	energy saving lighting	Sensing equipment	WIFI	Intelligent detection control	charge the phone	GPS	charging electric vehicles	public broadcasting	seat	connection management system
Los Angeles	√	√	√			√				
Stockholm	√									
Copenhagen	√	√		√						
Singapore	√	√	√							√
Barcelona	√	√								√
London	√									√
Paris	√		√		√				√	
Las Vegas	√	√	√		√					
Milton Keynes	√	√	√					√		√
Berlin							√			
Brisbane	√									
Amsterdam	√			√						
Montreal	√			√						√

Data source: Author collated according to relevant literature

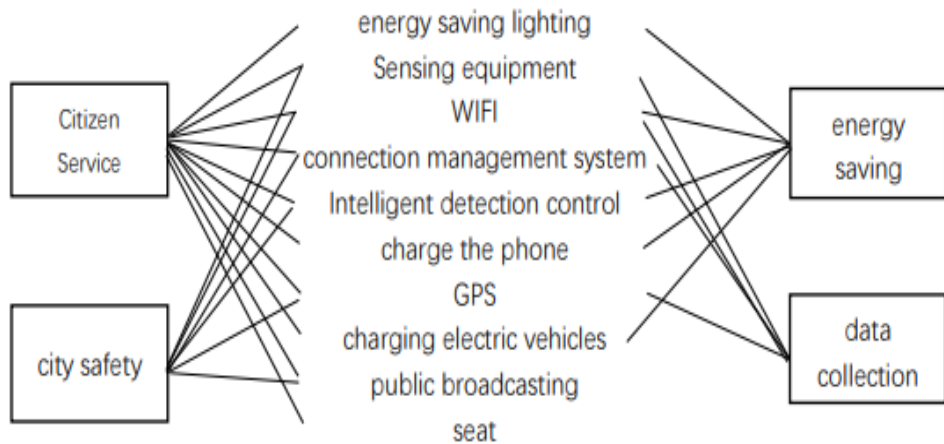


Figure 1 Functions and effects of smart lighting

Image source: the author's own drawing

3.3 Analysis of key points in the development of foreign road smart lighting

According to the summary results of the above cases, the development overview of smart road lighting mainly summarizes the following five characteristics:

3.3.1 Integration: upgrade and transform urban lighting infrastructure

In the cities in the case, the basic construction of urban infrastructure is complete, and the urban road street lights are still dominated by traditional street lights built in the city's early days. Many drawbacks have been exposed in the construction of modern smart cities, such as street light bulbs are high-pressure sodium lamps (Nathiyadevi, Aruthra, Anuraaghavi, & Karpagam, 2019). Mainly, the waste of electric energy is serious; the platform control and management methods are single, and the street lights cannot be accurately and timely reminded when there is a fault, which increases the later manual maintenance time and cost; lacks the function of collecting various information about the city. With the construction of smart cities, urban "amortization" has become the city's overall construction and development goal. Cities have begun to develop smart lighting by upgrading and transforming urban street lamps. For example, Copenhagen will install 20,000 energy-saving street lamps, Singapore will complete the renovation project of 110,000 street lamps, and Los Angeles will renovate 200,000 street lamps to provide services to citizens. Endow traditional street lights with new functions such as energy-saving lighting, WIFI, surveillance cameras, public broadcasting, sensor information collection, GPS, and convenience facilities, making them an important force to further promote urban development.

3.3.2 Conservation: use energy-saving materials and clean energy

Most of the countries in the case are large energy-consuming countries. Energy consumption will increase the burden of environmental problems, such as global warming caused by carbon dioxide emissions. The lighting equipment in the city is the main consumer of urban electric energy. The energy-saving transformation of the urban lighting equipment is one of the effective methods to save urban electric energy (Mukta, Rahman, Asyhari, & Bhuiyan, 2020). Cities such as Barcelona, Paris, and Brisbane are using solar energy, a clean power source, to develop smart lighting projects in their cities.

Urban street lights in Barcelona, Paris, and Brisbane have been retrofitted with solar panels and batteries to generate enough electricity to light the roads overnight. At the same time, LED energy-saving lamps are generally used in upgraded urban street lights, which improves the efficiency of power and energy use. In addition, the aluminum material design used on the top of Paris street lamps and the luminous materials used in Amsterdam roads directly and effectively promote the saving of electricity and energy. The use of these energy-efficient materials and clean energy has made a huge contribution to municipal energy savings and CO₂ emissions reductions in the region.

3.3.3 Networking: use a smart control management platform

In this case, the cities carried out the functional transformation of the urban street lights and improved the control and management platform of the urban street lights. In the construction of smart lighting in various cities, the sensing equipment and camera equipment installed in urban street lamps have become the key factors in the development of smart lighting. Sensing equipment and camera equipment can collect urban data information in terms of temperature, humidity, air quality, traffic conditions, etc. The street light control management platform will send the collected urban data information to the relevant urban management departments, thereby improving the city's various parts to solve urban problems. problem productivity. For example, in the case of Los Angeles, the vehicle can be detected in real-time, and in the event of a collision, information can be sent directly to the urban emergency communication system; in London, when the street lights need to be repaired or replaced, the iPad application control will send a reminder notification to the municipal engineer. In addition, the control and management platform in the case realizes the function of "lighting on demand", which can adjust the light intensity according to weather conditions or traffic flow, etc., which solves the problem of always-on road lights at night and alleviates the problem of urban energy waste (Imran, Latif, Farhan, & Tariq, 2019).

3.3.4 Convenience: Provide WIFI, seats, charging and other convenience facilities

In the construction of smart lighting, cities focus on the use and experience of citizens. To this end, many convenient designs have been added to it. For example Barcelona, street lights are equipped with small black boxes that receive signals, which can help blind people cross the road safely; Paris street lights, citizens can enjoy the experience of sitting under the lights to charge and connect to WIFI; Berlin, city light poles can charge electric cars; Milton Keynes, the street lights have the functions of CCTV, public broadcasting and WIFI, among which, the public broadcasting and CCTV are connected to the main control room of the MK Stadium, which can remotely play event information or other broadcasts; Montreal, improved the color and Contrast perception, which can improve the vision for users of different roads, and achieve the effect of "not disrupting the circadian rhythm of animals".

3.3.5 Cooperation: the government and enterprises cooperate to complete construction projects

The main participants in the construction of smart lighting in each city in this case are composed of local government departments and related enterprises. In its construction, the government provides policy guidance and financial support, while enterprises respond to the government's call to provide technical support and some financial support. Companies can participate in smart lighting construction projects invested by the government through fair competitive bidding. The government decides the winning bidder through comprehensive comparison based on the proposed design and construction plan. For example, to promote the development of smart urban lighting, Singapore has put forward stringent technical requirements in terms of products, control systems, and system integration and has sought and integrated advanced technical resources on a global scale. The project was bid by TELEMATICS of Singapore, Cisco of the United States, TELENESA of the United Kingdom, PARADOX of Japan, China Rongwen Energy Technology, Itron of the United States, and local partners. In the end, China Rongwen Energy Technology and the American Itron unit won the bid. In addition, the city's smart lighting construction also has public participation. For example, in Montreal, the construction of street lamps was based on the advice of residents. In order not to affect the nighttime rest of the residents in the area, the street lights near the park and the environmental public welfare area were changed to a warm color temperature of 1800K.

4. Results and Discussion

My country's smart lighting is in the initial stage of construction. Although there has been a certain development in recent years, there are still a lot of problems that need to be improved. For some foreign cities in developed countries, the development of urban infrastructure construction is relatively complete, the construction of smart cities started earlier, and there are also some effective construction projects in the development of smart lighting. Therefore, by referring to the successful cases of smart lighting construction abroad, sum up its successful experience, and combine my country's national conditions to explore the construction of smart lighting.

4.1 Use a variety of power supply methods, mainly self-sufficient power supply

In my country, traditional street lighting still occupies the vast majority of the lighting system. For the construction of smart lighting, the lamps can be replaced with LED energy-saving lamps to improve power supply efficiency. At the same time, solar panels and batteries can be installed on the street lights to increase the power supply mode of the street lights, mainly using solar power. In addition, the shape of the street lamp can be modified to increase its concentrating property and reduce the loss of the light source during the propagation process.

4.2 Use multi-party collaboration to promote the construction of smart lighting

For the construction of smart lighting in my country, multi-party cooperation can be used to complete its construction. my country's urban infrastructure has not yet been built, and the construction of smart lighting faces two aspects: the new area and the old area: the new area is in the construction stage, and the construction space is reserved for the smart lighting in its area; The upgrade and transformation realize the function of its smart lighting. Street lights are like the blood vessels and nerves of the city, covering every corner of the city. In the face of its huge construction volume, the way of joint operation and construction by the government and enterprises can be adopted. Using capital operation methods such as PPP (public-private partnership model) and EMC (contract energy management), break the administrative monopoly management, introduce financial monitoring methods, achieve a high degree of integration between the government and enterprises, and promote the construction of urban smart lighting in my country.

4.3 Realize the simultaneous construction of "road" and "network"

The smart lighting public management platform is the core component of smart lighting, and the smart lighting public management platform can be improved by establishing an information database. At present, although many areas in my country have carried out the intelligent transformation of lighting infrastructure, they are still using traditional lighting management systems, which are inefficient in collecting and integrating information and data. Relying on the existing urban lighting management system, establish an information database, standardize the format, further classify, integrate and collect various urban information data, and update the data regularly to ensure the effective construction of the database. At the same time, establish a transmission and sharing network between the database and various departments of the city, and transmit the collected real-time city information to the relevant management departments promptly, which can effectively improve the work efficiency of emergency rescue and disaster relief and ensure the safety of the city.

4.4 Combination of "Intelligence" and "Convenience"

The smart lighting equipment installed on the road can increase public participation and usage. For example, street lights provide public services such as WIFI, USB charging ports, seats, public broadcasting, temperature, and humidity display. This construction method can shorten the distance with citizens and make smart lighting deeply rooted in the hearts of the people

and an effective way to promote the construction of smart lighting. At the same time, an information-sharing platform can be established. The platform is connected with the database of the smart lighting public management platform to realize the sharing of urban data and information, so that citizens can obtain data and information related to life at any time, thereby improving the happiness of citizens and realizing the practical value of smart lighting. For example, basic information about the city such as road traffic conditions, air quality, and weather at various periods is provided. Citizens can obtain the latest information at that time through mobile APPs, WeChat public accounts, etc.

5. Conclusion

This paper summarizes the practical points of smart lighting by integrating the construction cases of road smart lighting in many foreign cities and provides some reference suggestions for the construction of smart lighting in my country. At this stage, the development of smart lighting in China is still in the initial stage of construction, and the task of urban infrastructure construction has not been completed. Compared with some foreign developed countries with complete infrastructure, my country has huge development potential in this regard. Therefore, in the construction of smart lighting in my country, on the one hand, the leading power of the government can be brought into play, and the government can be used as the main promoter of urban construction: promote the cooperation between the government and relevant enterprises, and cooperate to complete the transformation and upgrading of urban smart lighting facilities; promote the government's call for Use "green energy" to alleviate urban energy and environmental problems. On the other hand, the starting point of the construction is always to serve the people. Use the sensors, monitoring, and data collection platforms of smart lighting to collect and integrate real-time data in the city, improve the convenience of residents' travel and life, and improve the overall intelligence of the city.

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