



## Smart streetlamps as part of a smart city approach in Macau

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### Abstract

Smart cities are the mainstream trend of modern city development. With the promotion of the Guangdong-Hong Kong-Macau Greater Bay Area policies, Macau, as one of the four central cities in the Greater Bay Area, has pioneered the development of smart cities. The development goal of the smart city is to use modern electronic information technology to manage, coordinate, share efficiently, and interoperate the city's transportation, logistics, energy resources, and communication services. Comprehensive perception and information collection are the basis for its smart urban management. As one of the important node devices at the perception level of the smart city, smart street lights in Macau are not only the lighting infrastructure, but also include environmental monitoring, video surveillance, communication networks, Internet of Things, information interaction, charging piles and other economic functions of the people's livelihood. Under the above premise, this article discusses the urban policies, applications and prospects of smart streetlamps in Macau. At the same time, it compares the social nature and related policies of the mainland, analyzes the particularity of building smart streetlamps in Macau, and based on the application of smart streetlamps in Macau, propose optimization and development suggestions to promote the construction and development of Macau's smart city.

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### Keywords

*Smart streetlamps; Macau; smart city; Guangdong-Hong Kong-Macau Greater Bay Area; urban governance measures;*

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### 1. Introduction

With the advancement of science and technology, the elements of smart cities will become more and more diversified. From the perspective of data management, smart cities combine data analysis, processing, security, privacy, etc., to encourage application innovation and improve the efficiency of citizens' lives. A unified data management framework is very important for the application of smart cities. For example, install traffic monitoring equipment on street lights. Because the street lights are on the road and there is a power supply system, they can be perfectly combined to collect road information from all over the country, let the data be automatically processed and analyzed, and reported to the local transportation department and urban residents for effective management or tracking. Therefore, the overall quality of urban life can be improved (Fu Yidong, 2012).

At present, various countries and regions have researched Smart streetlamps, such as India (Velaga, N. R., & Kumar, A., 2012), Malaysia (Yusoff, Y. M., Rosli, R., Karnaluddin, M. U., & Samad, M., 2013), San Diego (Perry, T. S., 2018), Sheffield (Dizon, E., & Pranggono, B., 2021), Brunei (Ali, D. N. S. K. P., Au, T. W., & Suhaili, W. S., 2017), etc., and the construction of Smart streetlamps in Macau has started relatively Late, there is currently no relevant research

literature. In the current research on smart street lights, the main focus is on the dynamic control of the lighting system of the street lights (Ouerhani, N., Pazos, N., Aeberli, M., & Muller, M., 2016; Dheena, P. F., Raj, G. S., Dutt, G., & Jinny, S. V. 2017; Fujii, Y., Yoshiura, N., Takita, A., & Ohta, N. 2013; Salman, A. D., Khudheer, U., & Abdulsahab, G. M. 2019; Prasad, R. 2020), followed by the low-energy street light system combined with solar energy equipment (Velaga, N. R., & Kumar, A., 2012; Green, B. 2019) and smart street light network management system (Dizon, E., & Pranggono, B., 2021; 13) and related sensors and equipment components (Arjun, P., Stephenraj, S., Kumar, N. N., & Kumar, K. N., 2019). There is less research on the early deployment of smart street lights, but this has a positive role in promoting the development of smart street lights in cities. For example, Yusoff introduced the preliminary work of Smart streetlamps system development. He believes that before the full implementation of the Smart streetlamps system, Many factors need to be considered, such as wireless equipment, lighting energy saving, security features, etc. (Yusoff, Y. M., Rosli, R., Karnaluddin, M. U., & Samad, M., 2013). Dizon analyzed the characteristics of Smart streetlamps and the factors that need to be considered when deploying Smart streetlamps in Sheffield: deployment location, street lamp type, road type (Dizon, E., & Pranggono, B., 2021).

In summary, the advantages and effects of smart street lights in terms of energy-saving are obvious, and their equipment and network systems have gradually matured, and the urban issues that need to be considered for the deployment of Smart streetlamps need to be further explored. This article discusses the factors considered in the early deployment of Smart streetlamps. The deployment location of Smart streetlamps, the impact on the city, the types of street lights, etc., with the policy documents issued by the Macau government as the research background, combined with the surveying and mapping analysis of field investigations, reveals Macau The status quo and improvement ideas of smart city construction. The purpose is to lay the foundation for the comprehensive deployment of future intelligent street lighting systems and to lay a foundation for the establishment of existing technologies.

## 2. The development history of Macau's smart city

Macau is one of the core cities in China's Guangdong-Hong Kong-Macao Greater Bay Area<sup>1</sup>, one of the four largest bay areas in the world, and has a developed economy and GDP<sup>2</sup>. At present, Macau is building a smart city, and the design and promotion of Smart streetlamps is one of the important links, and it is inseparable from the policy guidance issued by the relevant departments of the Macau government.

The development of Smart streetlamps in Macau is closely related to the construction of smart cities. With the launch of the "Outline of the Twelfth Five-Year Plan for National Economic and Social Development", the concept of smart cities has been widely promoted and implemented in my country. According to the National Development and Reform Commission's statistical report, more than 500 cities in my country have proposed smart city development plans. At the same time, the Macau Special Administrative Region Government clearly set the development goals of Macau to build a smart city in the 2016 "Macau Special Administrative Region Development Plan (2016-2020)" and "Policy Address", and established a "Smart City Special Group" and the "Smart City Task Force" coordinated, promoted and promoted the related work of smart cities within the government, and since then launched the prelude to the development of smart cities in Macau. Since then, the development of smart cities in Macau has been accelerated in various departments and fields and has achieved remarkable results.

At the end of 2016, the Macau Science and Technology Development Foundation sponsored four professional teams to carry out the research activities of "Macau Smart City Development Direction and Strategy Research" and "Macau Smart City Development to Smart Travel Feasibility Study". Scholars, industry representatives, social organizations, investigate and visit, and hold relevant seminars and consultation meetings to collect opinions from the community. In 2017, the smart city development guidelines and policies that conform to the actual conditions of Macau were launched. The Macau SAR<sup>3</sup> Government and Alibaba Group signed the "Strategic Cooperation Framework

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<sup>1</sup> The Guangdong-Hong Kong-Macao Greater Bay Area (Greater Bay Area) comprises the two Special Administrative Regions of Hong Kong and Macao, and the nine municipalities of Guangzhou, Shenzhen, Zhuhai, Foshan, Huizhou, Dongguan, Zhongshan, Jiangmen and Zhaoqing in Guangdong Province. The total area is around 56 000 km<sup>2</sup>. Based on the latest figures provided by the Guangdong Province, the Hong Kong Special Administrative Region Government (SARG) and the Macao SARG, the total population in the Greater Bay Area is over 86 million and the GDP is USD 1,668.8 billion in 2020.

<sup>2</sup> Gross domestic product (GDP) is the standard measure of the value added created through the production of goods and services in a country during a certain period.

<sup>3</sup> Macao Special Administrative Region, is a special administrative region of China. Located west of the Pearl River estuary in Guangdong Province,

Agreement for Building Smart Cities", using Alibaba's cloud computing and big data technology to accelerate and complete the government's infrastructure construction and information technology for building smart cities reserve.

2018 is a year in which Macau has made great breakthroughs in smart city IoT technology. The University of Macau established the State Key Laboratory of the Internet of Things for Smart Cities. The Guangzhou Blockchain Industry Association, the Hong Kong Blockchain Industry Association and the Innovation Center of the University of Macau form the Guangdong-Hong Kong-Macao Greater Bay Area Blockchain Alliance to apply blockchain technology in smart health, smart tourism, smart finance, and smart logistics. At the same time, Macau Telecom and Tencent signed a memorandum of cooperation to use Tencent Cloud technology to cooperate in the fields of cloud computing, big data, Internet of Things and artificial intelligence in Macau.

In February 2019, the Macau Science and Technology Development Foundation and WeBank signed a cooperation agreement. The first cooperation project will use blockchain technology to achieve safer and more efficient entity identity authentication and data exchange, accelerating the popularization of electronic payments in Macau.

In May 2019, the Macau Smart Street Light Project was completed, integrating more than 20 functions such as smart lighting, 5G/4G communication micro base stations, flood monitoring, people flow monitoring, charging piles, etc., providing the SAR government in energy, transportation, public security, tourism, etc. This project provides services in multiple fields, achieve multiple uses with one shot, and help build smart cities.

In September 2019, China Mobile Hong Kong, China Mobile Guangdong, Macau Telecom, and Guangdong Communications Industry Association jointly established the "Greater Bay Area 5G Nagano Alliance", which has deepened the coordination of communications technology in the Greater Bay Area and promoted the development of the 5G ecosystem.

In December 2019, Bank of China United Net Union Clearing Co., Ltd., UnionPay International Co., Ltd. and Macau Pass Co., Ltd. launched a "cross-border wallet" service that facilitates cross-border mobile payments, breaking the barriers of mobile payment in the two places.

In April 2020, the Macau government issued the "2020 Policy Address", which specifically pointed out the development plan of creating a "digital Macau" through a new generation of information technology, and speeding up the construction of 5G networks, data centers, and digital infrastructure to improve the city. The level of intelligence in management, industrial development, government services, and social governance will promote the construction of smart cities such as smart government affairs, smart customs clearance, smart medical care, smart tourism, and smart transportation.

In June 2020, the General Office of the Ministry of Transport, the General Office of the People's Government of Guangdong Province, the General Office of the People's Government of Guangxi Zhuang Autonomous Region, the General Office of the People's Government of Guizhou Province, and the General Office of the People's Government of Yunnan Province issued the "About the Pearl River Water Transport to the Guangdong-Hong Kong-Macao Greater Bay Area" Implementation Opinions on Construction" to promote the construction of smart ports, smart waterways, smart ships and smart maritime affairs in Guangdong, Hong Kong and Macau. Accelerate the construction of smart port projects, advance the construction of the digital waterway of the Xijiang trunk line, advance the research and development and application demonstration of intelligent shipping in Guangdong, Hong Kong and Macau, promote the integrated application of Beidou navigation system, Internet of Things, cloud computing, big data and other information technologies in the field of water transportation, and promote the integration of information technology based on the area. Research and application of block chain global shipping service network platform.

### **3. Factors affecting the development and application of smart street lights**

As early as the "Macau Smart City Development Strategy and Construction of Key Fields" issued by the Macau government, the development of smart cities was divided into five development goals, seven development strategies,

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40 nautical miles west of Hong Kong, Macao's 23.5 sq km of territory comprises the Macao Peninsula, Taipa Island and Coloane Island and is inhabited by about 450,000 people.

13 key areas, and six pilot programs, of which six In the pilot plan, Smart streetlamps rank first, which is the primary goal of the Macau government to develop smart cities.

According to field investigations and records, the current Smart streetlamps in Macau are only installed at the intersection of Avenida da Amizade(see Figure 1). This section is dotted with office buildings, schools, casinos and hotels of different heights. It is one of the busiest sections of the Macau Peninsula.



Figure 1 Smart streetlamps in Macau (Image source: Screenshots by Cartography and Cadastre Bureau)

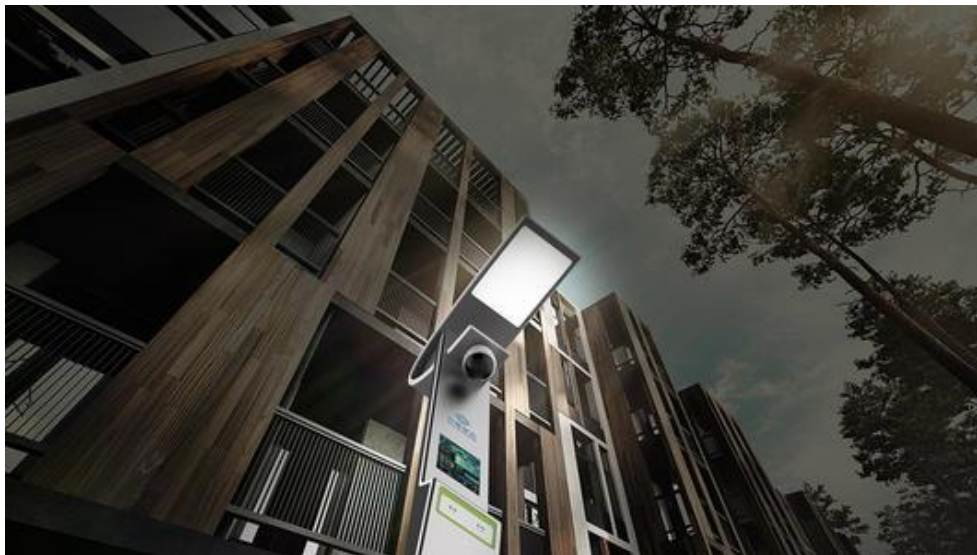


Figure 2 Night lighting of Smart streetlamps in Macau (Image source: Zhangshu Best News)

### 3.1 Considerations for the deployment

In terms of project planning, smart street lamps, as a new type of street lamps, have superior functions and technologies than traditional street lamps, but they also have certain limitations. At present, they cannot completely replace traditional street lamps and can only be used as urban street lamp systems. As a supplement and partial upgrade, the following three issues should be considered when planning and deploying Smart streetlamps:

### 3.2 Economic benefits of Smart streetlamps

The cost of traditional street lamps is low, and the material cost is only about 1,000 yuan. However, because of its high technology content and high equipment integration, the material cost of smart street lamps usually requires more than 100,000 yuan, and the price is dozens or even hundreds of times that of traditional street lamps, and smart street lamps The labor cost for maintenance and repair of precision equipment on the Internet is even higher.

Therefore, the deployment of Smart streetlamps must first weigh the economic viability of the site area after its placement, and can rationally use charging pile charging, billboard advertising rental and other functions and service recovery. A certain cost will form an economic closed loop to prevent Smart streetlamps from becoming a municipal fiscal "vampire" and "face-saving project" (Yusoff, Y. M., Rosli, R., Karnaluddin, M. U., & Samad, M., 2013). The deployment of Smart streetlamps in Macau is carried out in phases as planned. The initial goal is to optimize traditional street lights into LED street lights and save electric lights. Secondly, reasonable overall planning and comprehensive planning, arrangement of Smart streetlamps in neighbourhoods with high demand, new town reclamation areas, Cotai City and other suitable neighbourhoods, in an optimal way to let citizens and tourists experience the smart city development belt of Macau (Gassmann, O., Böhm, J., & Palmié, M., 2019).

### **3.3 The authenticity of the urban environment**

Macau has a long history of urban architecture and place culture, and the indigenous people have formed a stable place memory and place image on the site. According to the definition of place intention by American urban planner Kevin Andrew Lynch, places are composed of paths, edges, regions, nodes, and landmarks. Urban street lights have formed the role of nodes and landmarks in some places in Macau. For example, in Macau Rotunda de Carlos da Maia is a landmark of the site, it is not conducive to replace the original street lamp with a smart street lamp, so as to avoid the bias of the collective memory of the city (Clark, J., 2020).

### **3.4 Acceptance of local residents**

As an emerging product, smart street lamps have occasionally been controversial in news reports in recent years. For example, on August 24, 2019, individual citizens in Hong Kong destroyed the Smart streetlamps outside the Corporate Plaza in Kowloon Bay, Hong Kong because they were worried that Smart streetlamps would recognize faces and leak citizens' privacy. The emergence of such a phenomenon not only has local political and cultural factors, but also exposes the generation gap between the government and citizens. Therefore, it is necessary to carry out adequate communication with citizens and implement education and popular science before the deployment of Smart streetlamps, so that citizens can understand Smart streetlamps can have a positive effect on urban development and citizens' lives, avoiding unnecessary panic and suspicion for citizens (Houbing, S., Ravi, S., Tamim, S., & Jeschke, S., 2017). Even if it is known from the public information of government departments, the Smart streetlamps in Macau only collect relevant environmental data and traffic data, and do not involve personal privacy. But there are still many people who are not clear about its data collection. This will depend on further promotion by government departments to the public to explain their doubts.

### **3.5 Demand analysis**

Under the background of the construction of a modern smart city in Macau, the promotion of the construction of a world tourism and leisure center and a Sino-Portuguese trade platform, many urban public facilities in Macau need to be updated urgently to meet future needs. At the same time, with the support of the Macau SAR government, it is combined with the government. For the purpose of use by departments and citizens, the construction of Smart streetlamps also has the following six requirements:

#### **3.5.1 Boost the popularity of 5G networks**

On June 29, 2020, the first phase of the Macau 5G mobile communication network construction project was completed in June. It is expected that the full coverage of indoor and outdoor 5G signals within Macau will be completed by the end of 2021, and the service will be officially launched after the Macau SAR government issues a 5G license. Although Macau has built hundreds of 5G base stations so far, due to Macau's topography and urban environment, there are many street curves and steep slopes. The sea area is 85 square kilometers, and the distribution of land and buildings is uneven. Covering the construction of 5G networks poses certain challenges, and placing 5G micro base stations on Smart streetlamps can speed up its construction. The comprehensive coverage of 5G is the key to the subsequent improvement of smart tourism capabilities (Green, B., 2019).

### **3.5.2 Make up for the lack of urban charging piles**

According to statistics from the Bureau of Statistics and Investigation of the Macau Special Administrative Region Government (hereinafter referred to as the Bureau of Statistics), as of April 2020, there are 122,907 registered motorcycles in total Macau, accounting for about 20% of the total population. However, according to statistics from the Macau CEM Electric Power Company, 35 parking lots in Australia are equipped with charging stations for trams. Each parking station has about 1-9 charging parking spaces, for a total of about 180 charging stations, which is a huge gap with the number of trams. The charging pile interface reserved for Smart streetlamps in Macau can be used with parking spaces on the street, providing a certain degree of protection for the power supply of electric bicycles and even the future popularization of electric vehicles.

### **3.5.3 Optimize the organization of traffic passenger flow**

Traffic congestion has always been a common social problem in Macau. According to statistics from the Statistics Bureau, in 2014, there were about 240,000 motor vehicles in Macau, and the average speed of motor vehicles on Macau's main roads was about 12 kilometers per hour. Until 2016, there were more than 250,000 motor vehicles in Macau, an increase of 10,000 from two years ago, but the length of the road has not increased significantly, and the speed of motor vehicles is slow, which not only affects the driving experience of car owners, but also makes citizens wait for buses. The extended time has caused inconvenience in life.

Secondly, there are several ground repair projects in Macau every year, which not only did not significantly help to improve traffic, but even further deepened the phenomenon of road congestion. The Secretary for Transport and Public Works of Macau, Luo Liwen, said frankly about this: "There is no way." (Green, B.,2019)Macau Smart streetlamps collects the implementation status of road conditions through traffic monitoring equipment, and allows car owners and citizens to adjust travel routes and traffic modes according to actual conditions through remote control and information release, to a certain extent alleviate the problem of traffic congestion.

### **3.5.4 Reduce environmental pollution and power waste**

According to the Macau Energy Development Office report in June 2020, most of the roads and public outdoor lighting fixtures in Macau currently use high-pressure sodium lamps, about 14,000. The Civil Affairs Department of Macau stated that high-pressure sodium lamps consume a lot of energy and have a high failure rate, leading to increased maintenance costs including human resources, time, and parts. Compared with the high-pressure sodium lamp, the LED lamp of the smart street lamp has higher luminous efficiency and is more energy-saving. In 2013, the Civil Affairs Department of Macau completed the improvement project of the lighting in the actual condition of the roads, and installed 50 sets of 4m high 60W LED lights.

According to the report after the completion of the project, the total power consumption has been reduced by 53% compared with the previous year. In addition, its higher color rendering can make the field of vision clearer, and its longer light-emitting life can reduce the frequency of street lamp maintenance, which can improve driving safety and relieve mental stress on road traffic. At the same time, the LED lamp does not contain mercury, so it will not pollute the environment, and the material composition is more environmentally friendly.

### **3.5.5 Create a smart tourism brand image**

Although Macau has a history of more than 400 years of cultural convergence between Chinese and Western cultures, and has left some historical sites, but overall tourism resources are not abundant. In terms of resources, it is not outstanding. At the same time, a single tourism industry relies too much on the controversial gambling industry, which affects the positive development of Macau's tourism industry and is likely to form a stereotype of a "gambling city" and a city name card. Under the development strategy of smart cities, the development of smart tourism is not only the general trend, but also an opportunity for Macau to build a better tourism brand image. Liu Dingji, a professor at the Faculty of Business Administration of the University of Macau, said that smart tourism includes clothing, food, housing, and transportation, but Macau still has a long way to go(Perry, T. S.,2018).

As the infrastructure and support facilities of a smart city, Smart streetlamps can not only carry 5G base stations and drive the development of smart industries, but also provide data support for tourism applications (APP) through data collection from various testing equipment, enriching tourists' experience. The usage habits and experience of O2O (Online To Offline) enhance the convenience of tourists' travel (Figure 3). At the same time, the interactive display screen of Smart streetlamps can provide a platform for new media. There are more application scenarios in tourism guides, convenience information, cultural and creative products, public service advertisements, etc., and the use of video, pictures, animation, music and other communication media to allow tourists to perceive the city culture of Macau, improve the impression of Macau city, and create a more diverse city image (Macau Daily, 2019).

### 3.5.6 Improve city data collection capabilities

Smart applications in smart cities require the support of big data. The Secretary for Administration and Legal Affairs of Macau, Zhang Yongchun, stated in the Macau Legislative Council on June 11, 2020 that data is key to a smart city. At present, Macau needs to solve the problem of data collection and intercommunication. Smart streetlamps contain several data collection equipment, including noise, passenger flow, traffic flow, environment, public security, etc., and under the relatively high density and large number of street lights, it can effectively and accurately collect city data, which is an efficient application of big data.

### 3.6 Smart street lighting equipment analysis in Macau

The smart light poles in Macau combine the needs of multiple departments and the local characteristics of Macau. They are both functional and aesthetic. Broadly speaking, they have the following features (Guangdong Rongwen Technology Group Co., Ltd ,2020):

- 1) Adopting a "holistic" Smart streetlamps design, and the appearance of Smart streetlamps that are more in line with the local customs of Macau and the image of an international city, thereby enhancing the modern urban landscape of Macau (Figure 1);



Figure 3 Smart streetlamps in Macau (Image source: Photo by the author)

- 2) A cross-departmental integrated management platform that integrates up to 20 types of smart devices, and can carry 72m/s wind resistance and withstand the strict requirements of subtropical storm surge, supports multiple different business management departments, independent management of equipment, and unified deployment of communication interfaces (see Figure 3 );

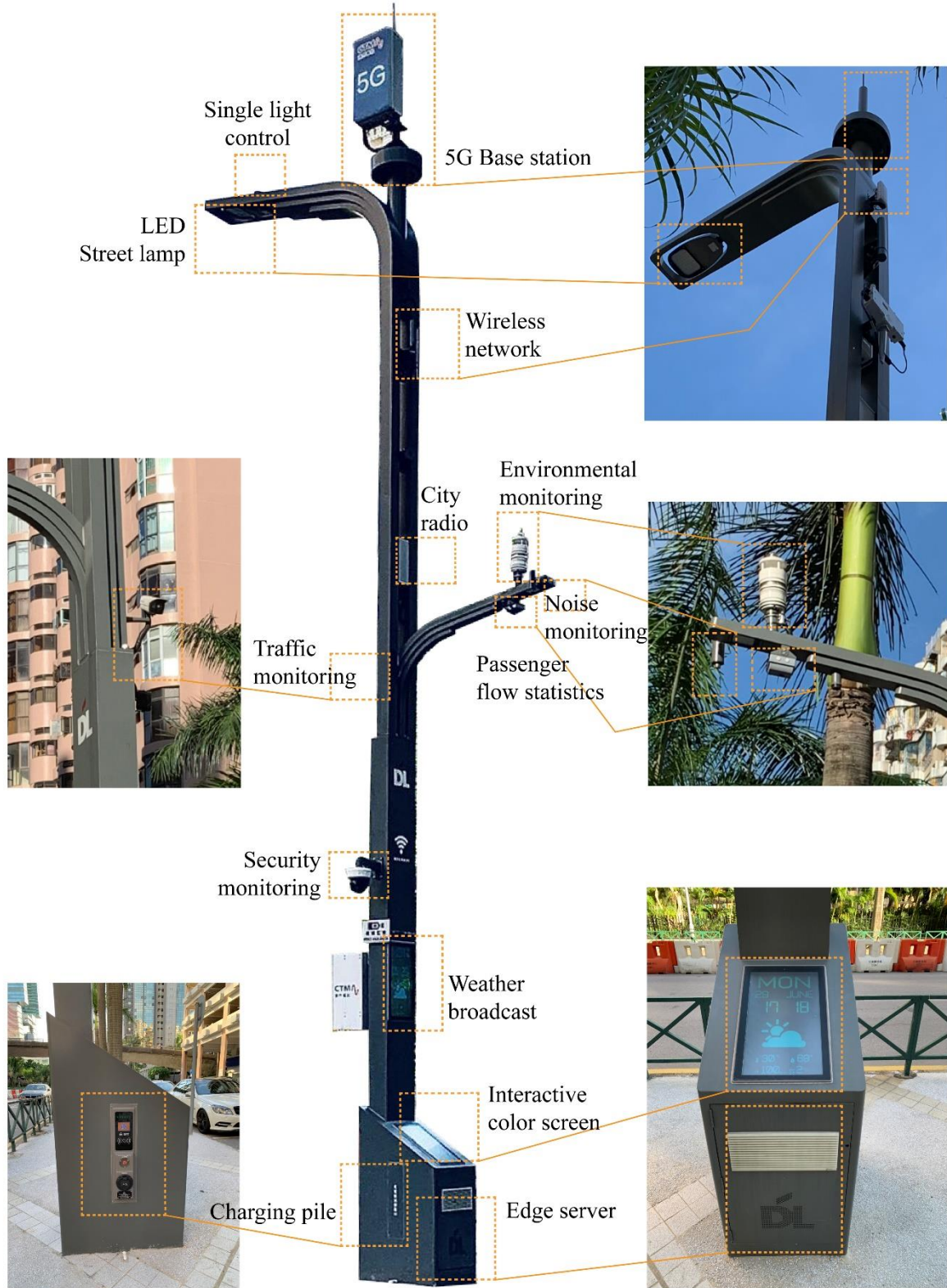


Figure 4 Function analysis of Smart streetlamps in Macau (Image source: drawing by the author)

- 3) Designed intelligent lighting: adopts IPv6+MESH wireless networking control technology for lighting control, multi-link design and each street lamp is equipped with a single lamp controller, which can realize remote control, lighting on demand, and the overall effect can save 70% of energy, The brightness is increased by 10%, and the management and maintenance cost is saved by 40%;
- 4) The IoT platform that integrates multiple communication methods, integrates 5G and 4G base stations, helps Macau to deploy massive and more densely scaled 5G site needs, while avoiding repeated construction and saving investment, it is on the light poles of Smart streetlamps Mount 5G micro base stations to realize the intensive construction, co-construction and sharing of infrastructure;
- 5) Smart light poles that integrate intelligent traffic and traffic monitoring, and support multiple alarm mechanisms for event linkage, to meet the needs of real-time urban data feedback processing for immediate alarms of abnormal situations and direct warning of major problems;
- 6) The LED weather screen of the Macau Geophysical and Meteorological Bureau (SMG) is linked with weather sensors to display local weather information to the public in real time.

#### 4. Conclusions and recommendations

At present, Smart streetlamps in Macau are still in the experimental application stage for the first time. Compared with some mainland cities, they are not the first to be carried out in the Guangdong-Hong Kong-Macau Greater Bay Area. Therefore, through the development of Smart streetlamps, we can see that Macau has a certain degree of contribution to the construction of smart cities. In addition, due to the legal division and protection of the historical urban area and the buffer zone of the world cultural heritage in Macau, some residential areas in the old urban area have not been able to put Smart streetlamps into use, so they are more restricted. In this regard, the research suggests:

- 1) From the perspective of urban style coordination: For new city reclamation areas, Smart streetlamps can be considered for deployment in urban planning and construction to make subsequent urban data detection and management more convenient; and for historical urban areas such as the Macau Peninsula In larger areas, the application of smart street lights is more difficult. If the original street lights were more modern and have a certain negative effect on the city, you can consider transforming them into smart street lights; for Taipa and Cotai City, there are more modern buildings and dense traffic. In the area, it is necessary to increase investment in the application of smart street lights to facilitate standardized management of urban traffic and urban crime prevention. At the same time, it should be considered that the appearance of smart street lights when used in different areas is consistent with the urban style of the area or the architectural style of the district, instead of using the same smart street lights in the entire Macau SAR.
- 2) From the perspective of Sustainable Development Goals, SDG 13: An international city with an economic boom like Macau is also facing the problem of resource consumption and carbon emissions. Through the monitoring equipment included in smart street lights, real-time coordination should be carried out on environmental, resource, and energy issues. Disaster monitoring from spatial data can provide guidance and warnings for effective disaster reduction in cities. Regarding each smart street lamp as a data monitoring point set up in the street, the administrative department can consider further establishing a method model of climate change parameters, data products with clear spatial information, and decision support for climate change response in the background system.

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