Smart Economic City: Current Status and Optimisation of Macau's Transport and Environment

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Abstract. The accelerated development of Macau over the past decade has led to an increase in demand for transportation and energy consumption, resulting in significant environmental and transportation issues. This paper examines both the transport and environmental aspects of Macau in light of the current situation and offers viable recommendations for future economic action.

Keywords: smart city · transport · environment · Macau · economic development

1 Introduction

1.1 The Driving Force of Policy on External Communication

Since its return to the People's Republic of China ten years ago, Macau has developed rapidly under the "one country, two systems" policy and with a high degree of autonomy. Parallel to this development, the demand for transport and energy consumption has skyrocketed, resulting in the escalation of Macau's transport and environmental problems. According to the Statistics and Census Bureau of the MSAR Government, the land area of Macau has increased from 29.9 Km^2 in 2011 to 33.3 Km^2 in 2022; however, the total population of Macau has increased from 557.4 Km^2 in 2011 to 672.8 Km^2 in 2022; in 2021, the population density of Macau has reached 20.7 thousand people/square kilometre. The total number of motor vehicles in Macau has increased from 206,062 in 2011 to 249,582 in 2022, as shown by the annual growth rate in Fig. 2. In addition, as a result of the gradual remission of the epidemic, the number of visitors to Macau will increase dramatically in 2023, from 606,841 in April 2022 to 1956,867 in February 2023, a growth rate of approximately 222%. In addition, the annual energy consumption per household per square metre in Macau increased by 16.5% in 2019 compared to 2017, the energy used per unit outside of government increased by 29.2%, and the energy consumption per unit in hotels rose by 38.0%. As a consequence, Macau is tiny, the roads are narrow, there are many people and many vehicles, and the demand for transport, as well as the environmental pressure, is rising dramatically. Macau requires a more scientific approach to find a solution to its significant traffic and environmental pressures. This section examines the problems and potential solutions from the perspectives of Macau's traffic light system, its transit, and its energy [1].

2   Analysis of the Current Situation

2.1   Analysis of Traffic Problems

Analysis of the Current Situation of the Traffic Light System in Macau
Due to Macau's compact size and limited roads, as well as the high number of people and vehicles, traffic jams are common. The rational application of the traffic signal
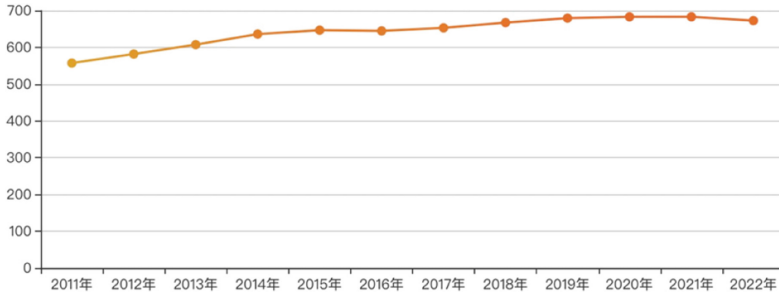

Fig. 1. Macau Demographics

2011 年	206,062	↑ 5.00%	1.37	37.13
2012 年	217,035	↑ 5.33%	1.56	42.72
2013 年	227,627	↑ 4.88%	1.71	46.90
2014 年	239,795	↑ 5.35%	1.86	50.73
2015 年	249,040	↑ 3.86%	1.97	53.75
2016 年	250,450	↑ 0.57%	2.04	55.45
2017 年	241,611	↓ 3.53%	2.11	57.77
2018 年	240,145	↓ 0.61%	2.15	58.82
2019 年	240,746	↑ 0.25%	2.29	62.72
2020 年	244,110	↑ 1.40%	1.66	45.47
2021 年	247,603	↑ 1.43%	1.93	52.94
2022 年	249,581	↑ 0.80%	1.68	46.16

Fig. 2. Statistics on number of motor vehicles (Left) and Public Bus Ridership (right)
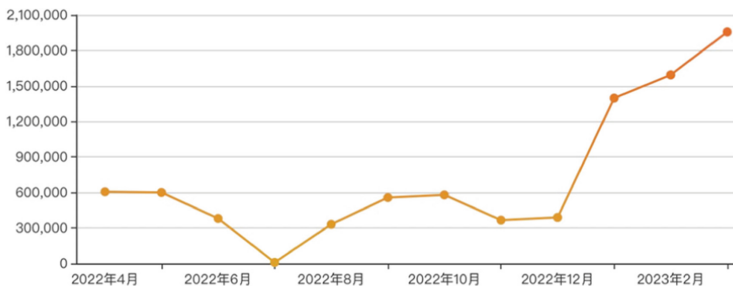

Fig. 3. Macau Arrivals Statistics

system is essential to the resolution of the traffic congestion issue. In recent years, the Macau administration has made significant efforts and advancements. According to the Transport Bureau of the Macau SAR Government, the installation of traffic area control systems at 15 intersections was completed in March 2021, resulting in a 10–15% reduction in travel time at the relevant intersections [2].

However, Macau continues to experience severe traffic congestion during prime commute hours, as the number of tourists has significantly increased since the eradication of the epidemic. Moreover, unlike other evolved smart cities that use automated traffic signals, Macau's traffic lights are still operated manually. Therefore, it will be necessary in the future to consider a more intelligent traffic signal system.

Analysis of the Current Situation of Public Buses in Macau

Due to the high cost and limited availability of vehicles and the extremely limited coverage of the Light Rail Transit (LRT), many Macau residents prefer to travel by bus because it is less expensive and covers a larger area. As the number of residents, students, and tourists rises, so does the demand for buses. As a consequence, bus operations are under intense duress [3].

As shown in Fig. 3, the average daily ridership of buses in Macau reached 525,100 in February–March 2023, an increase of 6.25 per cent compared to the same period in 2022. The Macau Transport Services Bureau has also implemented pertinent measures, such as a bus stop announcement application, a bus stop displays reporting system, a passenger estimation system for bus compartments, and parking space information. The Bus Stop Reporting App allows users to view bus routes, adjacent stops, bus vehicles at each stop, the number of stops away from the stop, traffic dynamics, and travel destinations. One can view the display at the bus stop to determine in real-time how far the bus is from the station. This is a tremendous convenience for bus-riding citizens and visitors [4].

However, compared to other regions with developed smart city construction, there are still numerous issues. Figure 1 shows that when people use the app for a bus stop, they can only see the number of stops the bus has made from the stop and no other information, such as the estimated wait time. The bus stop app makes it difficult for users to plan their journeys due to the inability to see the traffic flow on a specific street or the estimated duration of congestion in the traffic situation (Fig. 2). In addition, only a small number of restaurants and attractions are visible in the tourist destinations section (Fig. 3), so users must use other applications to obtain the desired information. When people are waiting at a bus stop, the display next to the stop displays the number of stops until the next stop but serves no other purpose [5].

2.2 Analysis of Environmental Issues

Despite its small size, Macau will charge 86,308 kms of water in 2021, an increase of 0.9% over 2020, consume 5,688 megawatt-hours of electricity, an increase of 5% over 2020, and dispose of 3.6% of its municipal solid waste [6].

Although the Macao Government has made some efforts in environmental protection in recent years, such as the gradual replacement of fuel vehicles with electric vehicles in public transport, the promotion of the encouragement of waste resource management, the legislation and enforcement of the "Plastic Restriction Order", the establishment of

monitoring stations for air quality, water quality, and environmental noise, and the environmental geo-information system, etc., the abysmal level of environmental protection in Macao is a major concern. Nevertheless, annual energy consumption remains extremely high. This is likely due to the fact that the Macau government provides residents with more free electricity and water, that some residents do not turn off their air conditioners or consciously conserve water throughout the day, and that energy-saving smart devices such as sound-controlled lights and streetlights with automatic brightness adjustment are rarely used in Macau. Macau's hotels are also highly developed, and large portions of the city are still lit up at night, resulting in significant energy consumption. Extreme energy consumption may result in the production of large quantities of greenhouse gases and air pollution in Macau, which, when combined with the small scale of Macau's ecosystem, may damage the local natural environment and have a negative impact on the ecosystem and species diversity. In addition, due to the high volume of refuse disposal, improper waste disposal may contaminate the local soil and water sources, having a negative impact on the environment and public health [7].

3   Suggested Solutions

It is difficult to resolve Macau's transit issues. However, the MSAR Government places a high priority on the development of a digital city. In the Five-Year Development Plan of the MSAR (2017–2020) released by the MSAR Government in 2016 and the Policy Address of the MSAR Government in recent years, specific requirements for the development of a smart city in Macau have been outlined. On August 4, 2017, it also signed the Framework Agreement on Strategic Cooperation in Building a Smart City with Alibaba Group. Under the terms of this agreement, Alibaba will facilitate Macau's progressive metamorphosis into a new smart city by utilising cloud computing technology. In addition, the robust financial resources of the Special Administrative Region of Macau provide the necessary conditions for the smart city proposal of Macau. It is suggested that Macau should study the smart city construction practices of the world's foremost cities and draw inspiration from them [8].

3.1   Traffic Lights in Macau

The installation of intelligent traffic lights in Macau can lead to the creation of systems such as the Coordinated Adaptive Traffic Light System (CATLS), which enables entirely automated red and green light timing adjustments. The SCATS system is already in widespread use in the United States, including in Atlanta and several cities in California. This system utilises sensors to determine real-time responses to traffic conditions. To detect traffic flow, the SCATS system employs sensors at each intersection that are embedded in pavement-embedded wire coils. In addition to distinguishing between various categories of vehicles, these sensors can also identify pedestrians on the sidewalk. These decisions are generated automatically by the proverbial computer. In addition, they are implemented in tiny increments so as not to impede the flow. Siemens Mobility offers a comparable system in Michigan that employs a central processor to apply algorithms to collected data and determine the optimal signal operation. After the system

was implemented on a popular thoroughfare in Michigan, tests revealed a 12 per cent reduction in weekday travel time and a 21 per cent reduction in weekend travel time. With the implementation of coordinated adaptive traffic lights in Macau, signal durations can be automatically adjusted based on real-time traffic conditions, optimising the time it takes for vehicles to cross intersections, thereby enhancing traffic efficiency, reducing congestion and accidents, and lowering emissions [9].

3.2 Macau Public Buses

The objective of a smart city is to employ the new generation of information and communication technologies, such as the Internet of Things, cloud computing, big data, and mobile applications, in order to achieve real-time sensing, dynamic monitoring, in-depth analysis, comprehensive integration, and optimal allocation of key information in the city's physical space. As one of the central components of the smart city technology solution as a whole, the Smart City APP is a crucial link between the city's infrastructure resources, public services, and citizens. For Macau's bus stop APP, although visitors can use bus stops to get general information about buses, other software or websites to learn about Macau's food and attractions, Macau's telemarketing APP to call taxis, or to check routes on a map, etc., there is currently no official APP or webpage in Macau that integrates all this information, which forces visitors to visit multiple websites to find it. Macau can refer to Visitoslo in Oslo, Norway, where you can see all the activities and attractions, restaurants, accommodations and various modes of transport in Oslo. All modes of transport in and around Oslo, including municipal and regional buses, trams, metro, local railways and ferries, are included in a single ticketing system. Therefore, visitors can find a great deal of information on a single web page, without having to navigate through multiple pages.

For bus stop displays, Macau can make them more versatile by adding a Wi-Fi network with area-wide coverage, a touch screen for maps and nearby travel resources, a USB port for charging, and a button to call the 9-9-9 assistance centre directly. In addition, the enormous displays can be utilised for advertising, resulting in economic benefits. There are currently operational examples of this in New York. The LinkNYC in New York is 2.9 m tall and has two 140 cm high-definition displays on either side; an Android tablet for accessing city maps, directions, and services, as well as making video calls; two free USB charging stations for smartphones; and a phone with free calls to all 50 states and Washington, D.C. The LinkNYC also provides the ability to make international calls using a phone card. Each LinkNYC has a switch that dials 9-1-1 directly. In addition, LinkNYC offers Wi-Fi wireless networking, covering the five administrative districts with free, encrypted, front-megabit wireless IoT service. Although Macau is equipped with Wi-Fi wireless networks in a variety of settings, there are few wireless networks that enable group coverage. As a result, citizens must connect to different Wi-Fi networks in different settings, such as on buses, where they must connect to a dedicated bus network, and in hotels, where they must connect to different wireless networks, which can cause a great deal of inconvenience. Consequently, Macau can transform its bus stop displays to include Wi-Fi wireless network, charging, city maps, information about attractions, and so on. People do not have to worry about their mobile phones running out of battery while waiting for the bus, they can use Wi-Fi

wireless network while waiting for the bus, and they do not have to go through multiple channels to collect information to fully access Macau's tourism resources [10].

3.3 The Environment of Macau

Numerous streetlights in Macau continue to operate at normal luminosity even when no one is present late at night, resulting in wasteful energy consumption. Therefore, the Macau SAR Government can implement smart streetlights, which can monitor weather and traffic conditions in real time via sensors and then autonomously modify their brightness and usage time in response. In addition, environmental monitoring can be performed using the sensors on these streetlights, and data can be shared with the city management system using Internet of Things technology. In addition, this smart street light can perform self-maintenance and diagnostic functions, automatically notifying the control centre when a problem occurs, thereby eliminating the need for manual troubleshooting. There are already several successful examples, such as Milan, Turin, and Bergamo I, where intelligent street lighting systems have reduced CO_2 emissions by 23,650 tonnes, 10,700 tonnes, and 1,600 tonnes, respectively. The government of Macau can also use smart metres to remotely read the water consumption of a household or water system, recording each customer's hourly water consumption and transmitting this data to the local public authorities responsible for water management, alerting customers directly if irregularities are detected. Additionally, the smart metre is integrated with an application that enables users to monitor consumption, compare data, and manage reports of excessive consumption.

The Spanish company Hidroconta has introduced a smart metre that is easy to install, requiring only a detection device and allowing users to download an application to view real-time water consumption data, compare consumption data across months and days, and generate reports to identify excessive consumption. In addition, Macau is situated in the Greater Bay Area and is encompassed by water, making it an island city able to fully utilise marine resources. In addition, as a renewable energy source derived from fluctuating sea levels, the government of Macau could contemplate using tidal energy to generate electricity. Tidal energy is environmentally benign, renewable, extremely predictable, cost-competitive, and reduces dependence on fossil fuels. As a pure energy source, tidal energy emits no greenhouse gases into the atmosphere, and although the initial construction costs are comparatively high, the long-term benefits in terms of return on investment can be realised in the long run. For instance, the La Rance tidal dam has been generating electricity since 1966.

Macau can also implement a customised thermostat within the building's infrastructure; this thermostat can heat the residence for less money without sacrificing the user experience. Using algorithms and the like, it can determine the most cost-effective method to heat the room and reduce greenhouse gas emissions. Several companies across the globe have already introduced HVAC systems, which are hybrid cloud-based systems that optimise the conversion between electric heat pumps and natural gas furnaces prior to use, thereby optimising energy savings. Adoption of these energy optimisation devices in Macau will not only reduce the negative impact of energy consumption on the environment, but it will also reduce operating costs and boost profitability, resulting in substantial gains for businesses, governments, and residents.

4   Conclusion

As a massive system engineering project, the primary goal of smart city construction is not only to improve people's standard of living and make their lives simpler but also to provide a pleasant experience for tourists. In recent years, Macau has experienced accelerated growth, but infrastructure development has not kept pace. In recent years, despite the emergence of numerous traffic and environmental issues, the Macau government has invested a substantial number of resources in the city's improvement. Simultaneously, it aims to learn from the success tales of other advanced smart cities and implement smarter solutions to Macau's traffic and environmental issues. Obviously, the solution to Macau's traffic and environmental issues also requires cooperation from citizens and businesses, such as conserving electricity and water and adhering to traffic laws and regulations, in order to support the implementation of a smart city and pave the way for Macau's urban development.

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