引用格式： LEUNG H, TO W M, CHUNG W L, et al. Smart city development and sound planning in Macao[J]. Technical Acoustics, **39**(5): 622-626.
DOI: 10.16300/j.cnki.1000- 3630.2020.05.016

Smart city development and sound planning in Macao

LEUNG H[1], TO W M[2], CHUNG W L[1], HUNG D[1], YEUNG M[1], IU K K[1]
(1. *Macau Instituto de Acustica*, *Macao SAR*, *China*;
2. *Macao Polytechnic Institute*, *Macao SAR*, *China*)

Abstract: Macao has developed rapidly over the past decade. In this period, there has been a significant increase in the number of infrastructure projects, ranging from the development of new districts, airport terminal extension, light rail transit and new roads in Cotai, to waste management and sewage treatment facilities. Some of these projects are in the planning stage, some being designed or under construction, and many already in operation. In order to integrate such a diverse range of infrastructure projects in a coherent manner and improve people's livelihood, the Macao government has embarked on smart city initiatives including smart mobility, smart healthcare, smart urban management, smart tourism, etc. The paper presents smart city initiatives and sound planning activities in Macao.

Key words: smarty city; sound planning; transportation; Macao

0 Introduction

Smart city is an evolving concept as the progress of smart-related infrastructures is phenomenal. These include smart buildings, smart transportation systems, smart utilities, ultra-high-speed broadband public wifi services, etc. Additionally, growth of smart personal devices is on-going, including smart phones, watches, wristbands and other wearables. With rapid advances of cloud computing, the Internet of Things and big data technology, and the development of artificial intelligence and deep learning, smart city can be a reality. This requires the government, private firms and local communities to actively participate in an open dialogue on the significance, purpose, and application of the smart city concept to the well-being of local communities, environments, and visitors.

This paper reviews the definition of smart city and, specifically, how it relates to Macao. The paper also explores the sound planning of Macao, focusing on the quiet light rail transit, and the city's new noise law and environmental impact assessment approaches.

Received: 2020-02-28; **Revised:** 2020-05-26
Author: LEUNG H (1973—), male, was born in Hong Kong, China. He received a master's degree in environmental management from the University of Hong Kong. His research fields are environmental science, engineering and management.
Corresponding author: TO W M, Email: wmto@ipm.edu.mo

1 Smart city and macao

1.1 Smart city

Transformation of a city to a smart one is a great challenge as it involves a multitude of stakeholders including the government, business firms, non-profit organizations, local communities and resdents, visitors, etc. A smart city cannot function appropriately without coordination between development, adoption and deployment of smart technologies. Besides, it demands changes of public behavior and adoption of a shared city vision[1].

The term smart city is not new. It can be dated back to the early 1990s in some government projects such as the Smart City Adelaide[2] and the Smart Valley-a subprogram of the Joint Venture Silicon Valley in the United States[3]. Yet, the term was not clearly defined until 2000 when Hall[4] suggested that a smart city is the urban center of the future, made safe, secure environmentally green, and efficient because all structures–whether for power, water, transportation, etc. are designed, constructed, and maintained making use of advanced, integrated materials, sensors, electronics, and networks which are interfaced with computerized systems comprised of databases, tracking, and decision-making algorithms.

In 2016, the United Nations Commission on Science and Technology for Development (UNCSTD)

reviewed the meaning of smart city and identified several key elements of smart infrastructure[5]. The UNCSTD report[5] suggested that a smart (and sustainable) city should be an innovative city using information and communications technologies (ICTs) and other means to improve efficiency of urban operation, services and management, and to improve the quality of life. Development of smart cities should meet the needs of both present and future generations with respect to economic, social and environmental aspects as proposed by the International Telecommunication Union[6]. The key elements include smart buildings, smart mobility, smart energy, smart water, smart waste management, smart health, smart digital layers, etc. Besides, other themes such as smart people, smart living, and smart economy should also be taken into consideration in achieving a real smart city. Since each city has a unique geographical, environmental, economic, political, social and cultural background, it is unrealistic to use a generic definition of smart city to suit all local contexts. Each city has to adapt the core meaning of smart city and adjust the elements for its own. Besides, the definition of a smart infrastructure also varies from time to time and from place to place[7-8]. For example, To et al.[8-9] reviewed the meaning of smart and sustainable buildings and found that it has changed quite substantially over the past decades. They solicited the importance ratings from Hong Kong's building professionals and found that intelligent security system was ranked as the most important attribute, followed by an intelligent and responsive fresh air supply and thermal control.

1.2 Macao and its definition of smart city

Macao is a special administrative region of China. It is located on the southwest side of the estuary of Pearl River. Macao was a Portuguese colony for more than 440 years and was officially reunified with mainland China in December 1999. The Macao government liberalized the gaming industry and approved three gaming concessions (later becoming six gaming concessions and sub-concessions) to different gaming operators in 2002[10]. Since then, Macao's gaming revenue (from casinos alone) has changed from MOP 24 billion in 2002 to a peak at MOP 361 billion in 2013, then to MOP 303 billion in 2018. Macao's gross domestic product has also changed from MOP 59 billion in 2002 to a peak at MOP 442 billion in 2014, then to MOP 440 billion in 2018. With an area of 32.9 km^2 and 0.67 million residents, Macao is the most densely populated city in China with over 20,000 people per km^2 in 2018. The total length of Macao's motor roads is 449 km. Macao has a total number of licensed vehicles of 0.24 million (0.11 million automobiles and 0.13 million motorcycles), causing a severe traffic problem that limits the city's mobility and livability. It is unsurprising that walking may be faster than driving or taking public transportation during rush hours.

In view of all the challenges and opportunities, the Macao government initiated a four-year smart city project in a form of a public-private partnership[11]. It signed an agreement with Alibaba aiming to utilize cloud computing and artificial intelligence to improve Macao's infrastructure management and public service efficiency, and reduce costs and consumption of resources. The first phase of the project was from August 2017 to June 2019 with an estimated budget of about MOP 0.4 billion. It aimed at applying artificial intelligence to enhance efficiency of the transportation networks, and improve tourism, quality of medical services and urban management, and ICT talent management. The Macao government has already used better/smart traffic control to reduce congestions, and divert crowds to different sight-seeing spots so as to avoid excessive noise that badly annoys residents in the vicinity of hot sight-seeing spots.

The second phase of the project will take place from July 2019 to June 2021. The aim includes continually refining Macao's ICT infrastructure, applying big data and artificial intelligence technologies to environmental protection and resource conservation, custom clearance and trans-border services, and modeling and forecasting economic changes. The budget for this phase has yet to be announced.

2 Sound planning related to smart city development

2.1 Quiet transportation mode

There are different transportation modes to move people freely within a city. Among them, mass rail transit is an efficient and environment-friendly solution[12]. Mass rail transit can transport a large number of people quickly without additional burden to the existing road networks.

Reducing urban traffic noise is an important consideration in the smart city development, especially in a densely populated and tourism-oriented city such as

Macao. To this end, a rubber-tyred light rail transit (LRT) system has been completed as Macao's mass tail trsit system. With this system, noise level has been significantly lowered as compared to conventional urban rail system using rolling stock with steel wheels running on steel tracks. [13]. Table 1 shows that typical noise levels emitted from steel-wheeled and rubber-tyred rail systems are very different. The noise data were extracted from the Shatin to Central Link (Tai Wai to Hung Hom Section) EIA Report[14] and the US Federal Transit Administration report "Transit Noise and Vibration Impact Assessment Manual"[15].

Table 1 Operational characteristics of rail systems

Rail systems	Wheel type	Max speed/ ($km \cdot h^{-1}$)	Sound Exposure Level (SEL)/dB(A)
Urban rail[14] (HK MTR)	Steel wheel	80	82.7
AGT (Rubber Tyre)[15]	Rubber tyre	80	78

Note: The US Federal Transit Administration report "Transit Noise and Vibration Impact Assessment Manual" published in 2018 indicated that the sound exposure level (SEL) at 15.2 m for electric Automated Guideway Transit (AGT) rubber tyre system should be 78 dB(A)[15]. Hence, the SEL at 25 m values given in the Shatin to Central Link (Tai Wai to Hung Hom Section) EIA Report should be 82.7 dB(A)[14].

Table 1 indicatess that noise emitted from rubber-tyred LRT is 4.7 dB(A) less than the stell-wheeled counterpart, contributing substantially to the reduction of traffic noise.

Noise from buses, automobiles, motorcycles and scooters vary significantly. It also depends on the operation mode, load, maintenance, weather condition, and even the drivers' behavior. Table 2 compares noise levels of these transportation modes.

Table 2 Noise levels of buses, automobiles, motorcycles, and scooters

Transportation mode	Noise levels/dB(A)	Source
Buses—diesel —electric	82 (SEL) 80 (SEL)	[15]
Automobiles	74 (SEL)	[15]
Motorcycles—sport	70.4 (L_{max})	[16]
Scooters	62.0 (L_{max})	[16]

Note: Sound levels were measured at a distance of 15.2 m from the center of the travel lane and 1.5 m above.

In March 2011, the Macao government signed a contract with Mitsubishi to manufacture the rolling stock and systems for Macao LRT. The construction works of Macao LRT depot, stations, and the elevated lines in Taipa and Cotai began in 2011 and subsequent years. It is expected that Macao LRT will mitigate traffic congestion, and also emit much lower noise and less air pollutants than other transportation modes as mentioned above. Macao LRT in a sense can enhance people's mobility and protect public health. It can be integrated with smart tourism to move a large number of people around the Cotai area efficiently. Figure 1 shows the route map of the Macao Taipa Line.

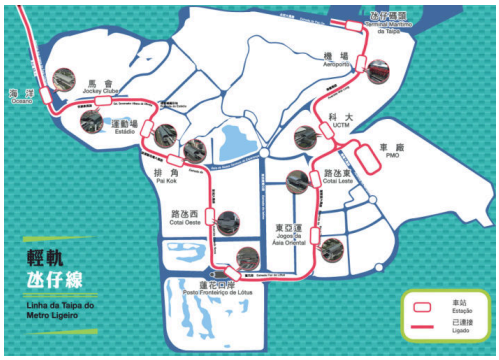

Fig.1 Route map for Taipa Line as of 8 September 2019 (from http://www.git.gov.mo/)

2.2 Noise impact assessment

Since 10 June 2018, the Macao government has started requiring certain private- and public-sector projects to conduct comprehensive environmental impact assessment. In this connection, the government released "A List of Designated Projects Requiring Environmental Impact Assessment" and a series of "Environmental Impact Assessment–Technical Guidelines". Specifically, noise impact assessment guideline covers potential noise sources, noise sensitive receivers, noise impact assessment methodologies, noise mitigation measures, and environmental noise monitoring and auditing approaches.

2.3 Noise law in Macao

On 22 February 2015, "The Prevention and Control of Environmental Noise Law" was enacted[10]. This law covers a wide range of environmental noise and community noise issues such as noise from construction sites, commercial ventilation systems, outdoor conducts, public places, residential activities and pets. To prepare the inaugural operation of the Macao LRT, this noise law was further amended on 12 April, 2019, to include control of noise arising from the maintenance work of LRT during noise sensitive hours. Figure 2 shows the government's flyers explaining the scope of Macao's noise laws and the associated penalties when they are breached.

Fig.2 Publicity materials for Macao's noise law (from http://www.dspa.gov.mo/)

2.4 Soundscape studies in Macao

Noise is generally known as unwanted sound, which has negative impacts on people and on the environment. Yet, sound in general is essential to our life as we need it to communicate, process information, and perceive surrounding activities. Hence, we need to focus on the positive attributes of sound. Soundscape studies can exploit the complex sound combination forming an immersive environment, and analyze its constitutive elements in the nature as well as in a man-made world. Soundscape is defined as an acoustic environment as perceived, experienced, and/or understood by people, in context[17]. The International Organization for Standardization has released two documents on soundscape in recent years[18-19]. Many soundscape studies have been carried out in North America and Europe[20-22], while few were carried out in Asia, particularly in Macao[23-25]. To et al.[25] presented a soundwalk study that explored the sonic environment at four Macao's UNESCO world heritage sites. Researchers of this study indicated that the sonic environment at Lilau Square was fairly pleasant with the highest degree of quietness and comfort among the selected sites, and with measured noise levels between 47.6 and 65.7 dB(A). On the other hand, the same group of researchers found that the soundscape was the poorest at Moorish Barracks in which envoronmental sounds were dominated by ventilation and vehicle noise in a reverberant environment, measured between 55.0 and 83.4 dB(A). In view of this, we suggest that a large-scale soundscape project be commissioned by the Macao government for achieving a good sound planning for the city.

3 Conclusion

This paper presents the background and sugnificance of smart city from a historical perspective. The Macao government initiatives concerning a number of steps in the past few years are highlighted. Big data and artificial intelligence technologies are used to improve people's mobility, health, and access to public services. As noise control and sound planning are important considerations in the smart city development, the Macao government has passed a noise law, which requires designated projects to perform environmental impact control including noise assessments. A quiet rubber-tyred LRT system has been in operation, contributing to the development of a environment-friendly smart city.

References

[1] DAMERI R P, ROSENTHAL-SABROUX C. Smart city–how to create public and economic value with high technology in urban space[M]. Springer, 2014.

[2] TOKMAKOFF A, BILLINGTON J. Consumer services in smart city Adelaide[C]//Proceedings of the International Working Conference on Home-Oriented Informatics, Telematics & Automation, Copenhagen, Denmark, 27 June–1 July, 1994.

[3] SAAL H J. Smart valley: an electronic community. A vision of our future[C]//Proceedings of IEEE Computer Society's International Computer Conference, California, the US, 28 February – 4 March, 1994.

[4] HALL R E. The vision of a smart city[C]//Proceedings of the 2nd International Life Extension Technology Workshop, Paris, France, 28 September, 2000.

[5] The united nations commission on science and technology for development. smart cities and infrastructure[R/OL]. Report Number: E/CN.16/2016.2, http://unctad.org/meetings/en/SessionalDocuments/ecn162016d2_en.pdf, 2016.

[6] International Telecommunication Union. smart sustainable cities: an analysis of definitions[R/OL]. Focus Group Technical Report, http://www.itu.int/en/ITUT/focusgroups/ssc/Pages/default.aspx, 2014.

[7] LEUNG H, WONG R, FOTHERGILL J, et al. Global trends in environmental noise control for a smarter city[J]. Technical Acoustics, 2016, **35**(6): 563-570.

[8] TO W M, LEE P K C, LAM K H. Building professionals' intention to use smart and sustainable building technologies – an empirical study[J/OL]. PLoS ONE, 2018, **13**(80): e0201625, https://doi.org/10.1371/journal.pone.0201625.

[9] TO W M, LAI L S L, LAM K H, et al. Perceived importance of smart and sustainable building features from the users' perspective [J]. Smart Cities, 2018, **1**(1): 163-175, https://doi.org/10.3390/smartcities1010010.

[10] TO W M, CHUNG W L. A comparison between noise legislations in Macao, other Greater China regions, and Singapore[J]. Technical Acoustics, 2016, **35**(5): 453-457.

[11] Macao Government Information Bureau. Developing Macao as a smart city to optimise services to the public[R/OL]. Macao Government Information Bureau, Macao SAR, China, https://www.gcs.gov.mo/showNews.php?DataUcn=114861&PageLang=E, 2017.

[12] TO W M. Centrality of an urban rail system[J]. Urban Rail Transit, 2015, **1**(4): 249-256.

[13] Macao transportation infrastructure office. progress for the Macao LRT[R/OL]. Macao Transportation Infrastructure Office, http://www. git.gov.mo/en/history.aspx, 2018.

[14] Hong Kong Environmental Protection Department. EIA Report for the Shatin to Central Link (Hung Hom to Tai Wai Section)[R/OL]. Hong Kong Environmental Protection Department, https://www.epd.gov.hk/eia/register/report/eiareport/eia_2002011/EIA/html/EIA_index.htm, 2011.
[15] The US Federal Transit Administration. Transit Noise and Vibration Impact Assessment Manual[R/OL]. The US Federal Transit Administration, https://www.transit.dot.gov/sites/fta.dot.gov/files/docs/research-innovation/118131/transit-noise-and-vibration-impact-assessment-manual-fta-report-no-0123_0.pdf, 2018.
[16] The US National Park Service. Motorcycle noise in a park environment[EB/OL]. The US National Park Service, https://irma.nps.gov/DataStore/DownloadFile/474440, 2013.
[17] Schulte-Fortkamp B. Soundscape, standardization, and application[C]//Proceedings of Euronoise 2018, Crete, Greece, 27 – 31 May, 2018.
[18] ISO. ISO 12913-1: 2014 Acoustics - soundscape - part 1: definition and conceptual framework[S]. Geneva: International Organization for Standardization, 2014.
[19] ISO. ISO 12913-2: 2017 Acoustics - soundscape - part 2: data collection and reporting requirements[S]. Geneva: International Organization for Standardization, 2017.
[20] SCHAFER R M. The soundscape: our sonic environment and the tuning of the world[M]. Inner Traditions/Bear & Co, 1993.
[21] BOTTELDOOREN D, et al. Soundscape of European cities and landscape: understanding and exchanging[C]//Proceedings of COST TD0804 Conference: Soundscape of European Cities and Landscapes, Merano, Italy, 22 March 2013.
[22] KANG J, ALETTA F. The impact and outreach of soundscape research[J]. Environments, 2018, **5**(5): 58-67.
[23] TO W M, CHUNG W L. Opportunities for soundscape appraisal in Asia[C]//Proceedings of Euronoise 2018, Crete, Greece, 27–31 May, 2018.
[24] CHUNG W L, TO W M. Identification of a city's soundscape using soundwalks[J]. Technical Acoustics, 2016, **35**(6): 500-503.
[25] TO W M, CHUNG A. Soundscape for smart tourism in Macao, China[J/OL]. Proceedings of Meetings on Acoustics, 2019, **36**(1): 040001, https://doi.org/10.1121/2.0001006.

澳门智慧城市建设与降低环境噪声的进展

梁浩贤[1]，杜伟明[2]，钟伟梁[1]，洪汉杰[1]，杨国良[1]，姚景光[1]
(1. 澳门声学学会，中国澳门；2. 澳门理工学院，中国澳门)

摘要：澳门在过去十年中迅速发展。同时，基础设施项目数量大幅增加，包括新区的发展，机场航站楼的延伸，轻轨交通，路凼的新道路，以及废物管理和污水处理设施。其中一些项目还处于规划阶段，一些正在设计中，一些正在建设中，另一些正在运营中。 为了整合各种各样的基础设施项目，改善民生，澳门政府已着手实施建设智慧城市，智慧医疗，智能城市管理，智慧旅游等的举措。文章介绍了澳门智慧城市的建设与降低环境噪声的进展。

关键词：智慧城市；噪音策划；运输；中国澳门
中图分类号：TB53 **文献标识码**：A **文章编号**：1000-3630(2020)-05-0622-05