

Article

Spatial Techniques to Visualize Acoustic Comfort along Cultural and Heritage Routes for a World Heritage City

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Abstract: This paper proposes to visualize acoustic comfort along tourist routes. Route-based tourism is crucial to the sustainability of tourism development in historic areas. Applying the concept of route-based tourism to guide tourists rambling along cultural and heritage routes can relieve overcrowded condition at hot scenic spots and increase the overall carrying capacity of the city. However, acoustic comfort along tourist routes is rarely addressed in academic studies and decision-making. Taking Macao as an example, this paper has studied pedestrian exposure to traffic noise along the cultural and heritage routes. The study is based on a GIS-based traffic noise model system with a high spatial resolution down to individual buildings along both sides of the street. Results show that tourists suffer from excessive traffic noise at certain sites, which may have negative impact on the promotion of route-based tourism in the long run. In addition, it is found that urban growth affects urban form and street layout, which in turn affect traffic flow and acoustic comfort in urban area. The present study demonstrates spatial techniques to visualize acoustic comfort along tourist routes, and the techniques are foreseen to be used more frequently to support effective tourism planning in the future.

Keywords: spatial techniques; acoustic comfort; cultural and heritage route; route-based tourism

1. Introduction

Cultural tourism is one of the fastest growing segments in global tourism and has been a major focus of interest for both international and domestic tourists. In Asia, particularly in post-colonial cities, the interest in cultural tourism has been strengthened by the concept of cultural heritage and the importance of the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage Sites [1,2]. Cultural heritage can be tangible and intangible [3]. For the former, the cultural heritage refers to buildings, monuments, landscapes, and artifacts. In the past two decades, route-based tourism has been suggested by linking scattered cultural and heritage sites into tourist routes to tell distinctive stories, or to create interesting tourism themes to visitors [4–7]. One of the earliest and most famous tourist routes is the Santiago de Compostela Pilgrims Way developed by the Council of Europe in 2002 [7].

In addition to the promotion of tourism market, route-based tourism is particularly crucial to the sustainability of tourism development in historic areas. Considering that historic culture and heritage sites are usually very compact in space and easily to be overcrowded, applying the concept of route-based tourism to guide tourists rambling in adjacent areas can reduce the pressure of particular sites, increase the overall carrying capacity of the city, and thus maintain the sustainability of tourism development in long term.

Previous studies have focused on a number of aspects to help create successful tourist routes, such as providing good support infrastructures, accessibility, visual information, city map guide, aesthetic landscapes, *etc.* [4,6,8]. In particular, new forms of communication technology such as smartphones have been applied for improving the visibility and promoting cultural heritages to tourists [9–11]. To enhance the promotion of cultural tourism, advanced technologies are essential for creating maps and location-sensitive information. Ghadirian and Bishop [12] have proposed an approach for displaying an urban landscape defined by maps made with Geographic Information System (GIS) tool. Scolozzi *et al.* [13] have developed a spatial valuation methodology for identifying and mapping tourists' perceived landscape values and related threats.

Nevertheless, the acoustic comfort along tourist routes is rarely addressed in academic studies and decision-making. In some Asian cities, due to the common existence of compact urban form, dense population, and the lack of control over the number of vehicles, ambient noise level on streets may be over the national or international standards. Although Asian residents (including those living in the authors' city) may have a higher tolerance to traffic noise, foreign tourists from developed countries may be uncomfortable when rambling along a street with high traffic noise, which in turn endangers the reputation of tourist sites in Asian cities. In order to have a competitive tourism environment, there is an urgent need to raise the attention of Asian governments on protecting the acoustic environment in the tourist sites, particularly along the routes connecting UNESCO world heritage monuments.

Noticeably, excessive exposure to noise might be considered a health risk, in that noise may contribute to the development and aggravation of stress-related conditions such as high blood pressure, coronary disease, ulcers, colitis, and migraine headaches [14]. In this regard, Asian governments should also pay more attention to the protection of acoustic environment for local residents in long term.

To undertake a noise impact assessment, traffic noise prediction models have been designed by different countries. Typical ones include the United States Federal Highway Administration Traffic Noise Model (FHWA-TNM) [15], the model by the Acoustical Society of Japan (ASJ) [16], the Calculation of Road Traffic Noise (CRTN) model in the United Kingdom [17], and the (Richtlinien für den Lärmschutz an Straßen) RLS90 model in Germany [18]. Some models (such as the former two) are developed based on the assumption of point emission source for traffic noise emission, while some models (such as the later four) assume line emission source. Whatever the assumptions used, these models usually have a common need to collect a number of urban data such as traffic conditions (*i.e.*, traffic volume, traffic composition, traffic speed), road gradient, road surface nature, absorbent ground cover percentage, street configuration, and distance between the traffic emission source and the receptor. Noise mapping by modeling techniques requires processing a large amount of these complex geographically referenced data.

In addition, noise mapping in historic areas needs a higher spatial resolution to support effective tourism planning, urban planning, and risk management, which in turn requires processing more geographically referenced data. The reason is that organic growth of residential buildings leads to complicated urban geometries and traffic conditions in historic areas. Noise level may then vary considerably in front of each building façade along the streets. Therefore, it has a strong desire to integrate traffic noise models with GIS that enables capture, modeling, manipulation, retrieval, analysis, and presentation of geographically referenced data. The GIS is an important tool in spatial analysis and modeling. A number of researchers have used the integrated GIS traffic noise prediction models to estimate the level of noise in urban areas [19–24].

This paper applies a GIS-based traffic noise model system developed by the authors to generate high spatial resolution maps of noise pollution along the cultural and heritage routes in Macao. Macao is selected in this study as it is a world heritage city which has just been recommended as “Best in Travel” for 2015 [25]. Macao is also famous for being one of the largest gambling hub and the fourth richest territory per capita in the world. As shown in Figure 1, Macao sits at the southwest corner of the Pearl River Estuary. The Estuary, with important cities like Hong Kong, Guangzhou (the capital of Guangdong province), Shenzhen and Zhuhai (two of the original Special Economic Zones established in the 1980s on the southern coast of Guangdong), has been one of the fast growing regions in China since the launch of the economic-reform and open-door policy in the 1970s [26,27]. In 2014, the annual average number of tourists of Macao reached 31.5 million, which was half of the figure in the neighboring city Hong Kong, despite that Macao’s population (~631,000) and territory (31.3 km²) are only 3% and 8%, respectively, of Hong Kong [28]. Recently, Macao is suffering from overcrowded tourists in the hottest spots. To address the problem, the local government has promoted cultural and heritage routes to direct tourists to the rest areas in the Macao Peninsula. Considering the recent announcement of new cultural and heritage routes in February 2015, and the significant role of these routes on the sustainability of the city in the future, it is necessary to investigate the acoustic environment along the cultural and heritage routes. The details of Macao and its cultural and heritage routes are described in Section 2. The model system has been developed, verified, and discussed in our previous work [23,24] and a brief description on the application of spatial techniques to visualize acoustic comfort is given in Section 3. Acoustic comfort along the cultural and heritage routes is presented in Section 4. The results could help decision makers to develop effective strategies to

improve acoustic environment and protect the World Cultural Heritages in Macao. Finally, the conclusions are given in Section 5.

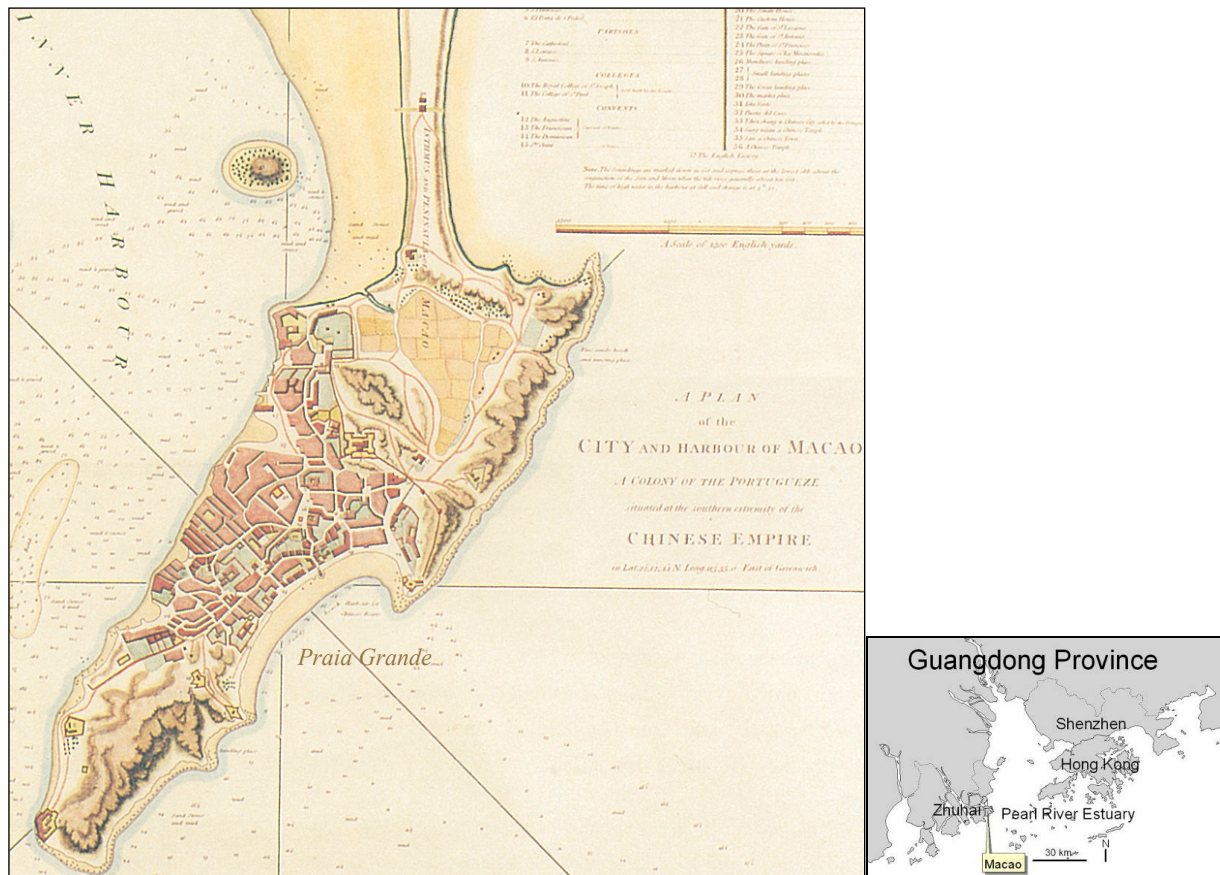


Figure 1. British drawing of Macao Peninsula in 1796 [26] and neighboring cities of Macao [27].

2. Study Area

2.1. Macao: Two Glorious Periods

Heritage sites might only experience one glorious period when they were built in the old days. Nevertheless, the heritage sites in Macao have experienced two glorious periods, one in the age of discovery (four centuries ago) and one nowadays. The two glorious periods are in line with the economic boom of Portugal and China, the two administrators appearing in the history of Macao.

The first glorious period was during the age of discovery, when the Chinese Emperor gave tacit approval of the Portuguese occupation in a portion of the Macao Peninsula in 1557. The Portuguese established their monopolistic position in trade with China. By 1563, 900 Portuguese and several thousand foreigners, “as well as Chinese”, occupied the settlement. Commercial houses, churches, large residences and some public buildings were built [29]. As the most important city for trading with China, the British, French, Danish, Spanish and Swedes settled their commercial houses in Macao and some European countries surveyed the geography and water depth in detail for trading and military purposes centuries ago (see Figure 1). In particular, the King of Portugal officially recognized the importance of this thriving settlement two times, when it was bestowed as the Crown Status of a City in 1565, and the City of the Name of God in 1587. As concluded by UNESCO, “Macao, a lucrative

port of strategic importance in the development of international trade", "*bears witness to one of the earliest and longest-lasting encounters between China and the West*" [30].

The second glorious period started twelve days before 2000, when Macao reverted from being a Portugal colony to being a special administrative region of China. Since then, Macao becomes the only city in China to permit gambling for at least 50 years, under the innovative "one country two systems" model [27]. Considering the unsustainable nature of the traditional manufacturing industry due to the shortage of land and labor, and also anticipating the abolition of Macao's export quotas in the international garment trade by the World Trade Organization, Macao defined her long-term economic strategy in 2002 that gaming-led tourism would be the driving engine for economic development and the tertiary service industry would be the priority sector. With the spread of large casinos as well as the economic boom in China, the legend of Las Vegas happens again in Macao. By 2013, Macao has cemented its status as the undisputed heavyweight champion of the gambling industry, as its gambling revenue reached US\$45 billion, which is seven times greater than Las Vegas. According to the World Bank, Macao even overtook Switzerland as the fourth richest territory per capita in the world. The media concluded dramatically that "*Casinos beat the banker*" [31].

Another comparative advantage of Macao stems from the conservation of the historic area by the Portuguese and the successive branding strategy by the Chinese. A 400-year history of European settlement has implanted an image of Macao as a European city [29]. In this regard, the Portuguese governors started to award protected status to certain urban areas and buildings two decades before the unification and made funds or tax deductions available to proprietors for restoration works. Five years after the unification, the Historic Center of Macao, China's only 2005 submission for World Heritage listing, was awarded "World Cultural Heritage" status by the UNESCO, citing the "*dramatic mixing of eastern and western buildings in this jewel*". The tangible cultural heritage monuments recognized by the UNESCO are located inside zone 1 and zone 2, as indicated in Figure 2, and a detailed description will be given in Section 4. Intangible cultural heritages such as Cantonese Opera, Herbal Tea, Woodwork–Religious, Cantonese Naamyam, Taoist Ritual Music, and Feast of the Drunken Dragon are demonstrated in Figure 3.

The award for World Cultural Heritage together with the gaming developments further boosted the tourism economy. At the end of 2014, one of the largest travel guide book publisher, Lonely Planet, recommended Macao as one of the top 10 regions to explore in 2015, citing "*Macau has grown into a mélange of new world glamour and old world grit. Its Portuguese heritage has created a fusion cuisine that combines European, African, Indian and Chinese elements. Where else can you make an incense offering at an ancient Chinese Buddhist temple, take the world's highest bungee jump, have a Michelin-star meal and a street food midnight snack? And with a new light rail system in the works, plus a slew of new casinos under construction, 2015 promises to be a banner year*" [25].



Figure 2. UNESCO heritage sites and overcrowded condition in the core of the Historic Center of Macao. Source: UNESCO and Macau Government.

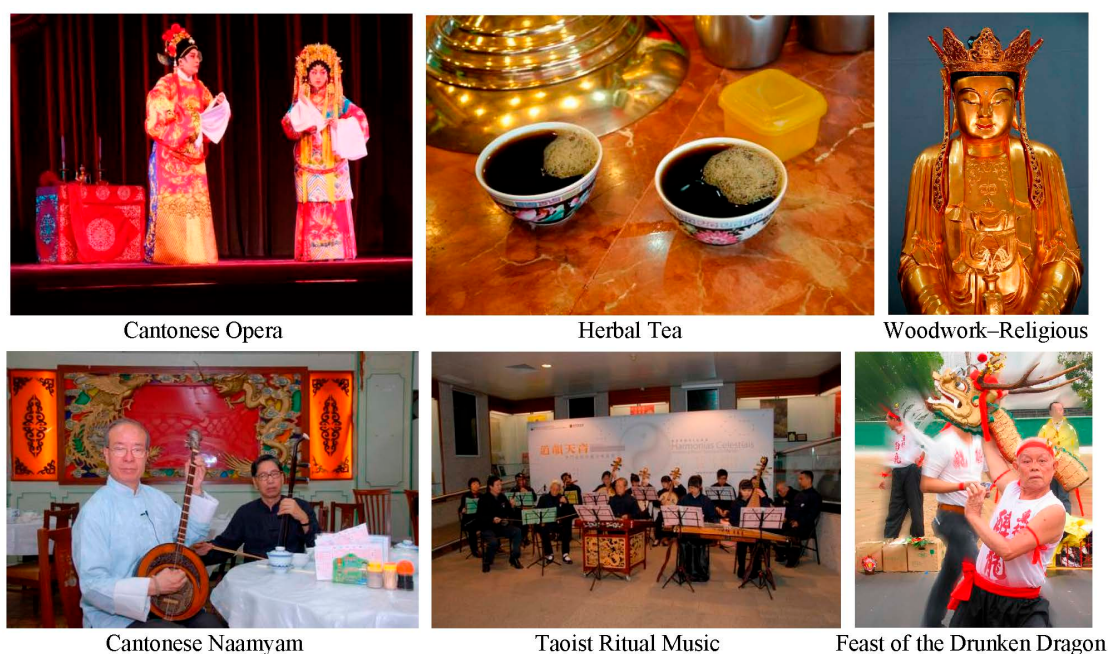


Figure 3. Intangible cultural heritages recognized by the nation. Source: Macau Government.

2.2. Cultural and Heritage Routes: A Way to Reduce Negative Impacts of Booming Tourism

According to the UNESCO, the inscribed property in the Historic Center of Macao presents a group of 22 principal buildings and three historic squares. Almost all the tourists will enter the Historic

Center of Macao to experience the UNESCO World Cultural Heritage for their first visit. Nevertheless, the majority of tourists visit only a tiny portion, e.g., the Senado Square and the Ruins of St. Paul's, and thus the hottest spots are suffering from overcrowded tourists. In particular, during important festivals such as Chinese New Year, crowd control measures have to be implemented for safety considerations (see Figure 2).

In order to direct tourists to other areas, the government has announced cultural and heritage routes for rambling in the Macao Peninsula. In February 2015, the number of routes has increased to six, namely (1) Footsteps into the Historic Centre; (2) Crossroads of China and Portugal; (3) The Marriage of East and West in St. Anthony's Parish; (4) An Experiment of Creativity; (5) Enchanting Stories of Our Lady of Fatima Parish; and (6) A Legacy of Arts and Culture. The length of each route is around 1.3–2 km and the walking will take half an hour for most routes, as suggested by the government. The walking speed is then expected to be 0.8–1.3 m/s, depending on the unique characteristics in each route. Figure 4 shows the spatial distribution of the six routes in four urban areas of the Macao Peninsula. The four urban areas, namely Urban Areas 1, 2, 3, and 4, are divided according to four stages of urban growth in the Macao Peninsula, *i.e.*, 1557–1794, 1794–1912, 1912–1957, and 1957–present. The layout of the six routes shows the government's ambitious to direct crowded tourists in the hottest scenic spots towards the north border gate and the rest boundary along the coast (see Figure 4), so as to reduce the negative impacts of the booming tourism and maintain the carrying capacity on behalf of sustainable development.

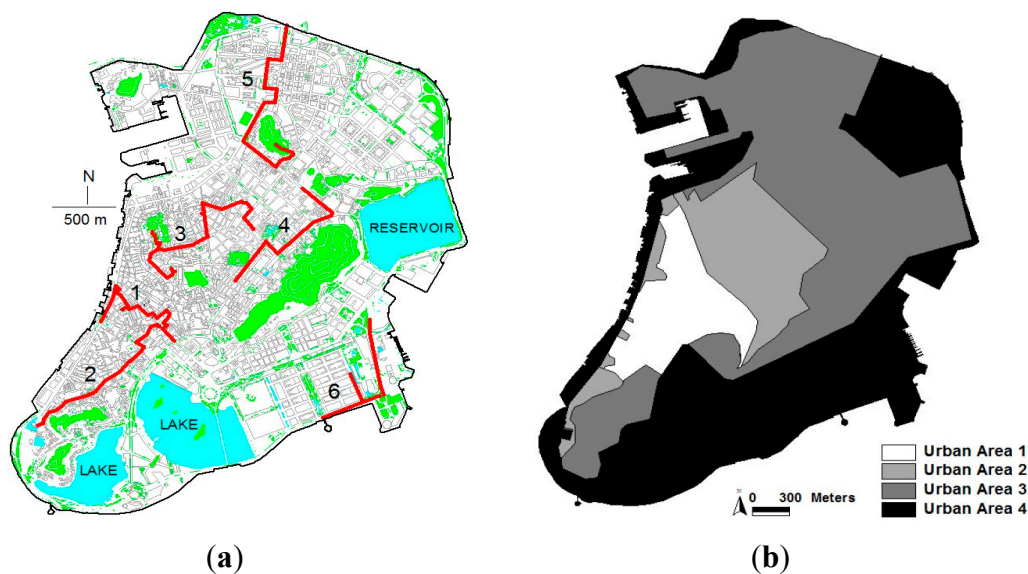


Figure 4. (a) Six official cultural and heritage routes; and (b) Urban Areas 1, 2, 3, and 4, developed during 1557–1794, 1794–1912, 1912–1957, and 1957–present, respectively.

3. Spatial Techniques to Visualize Acoustic Comfort

The United Nations World Prospects Report (2004 revised) listed Macao as the No. 1 most densely populated region in the world. As the traditional core, the Macao Peninsula's population density reaches 53,400 inhabitants per square kilometer. The urban form in the peninsula is therefore extremely compact due to the population growth and the shortage of land resources. Considering the spatial

nature of urban structure and noise distribution, the authors have developed a GIS-based traffic noise model system with a high spatial resolution down to individual buildings along both sides of the street. The system integrates the road traffic noise model CRTN [17], digital maps, administrative databases, an urban landscape model and the GIS. Details of the model system have been presented in our previous work [23,24]. To the convenience of the reader, a brief description of the model system is given below.

The traffic noise levels along the pedestrian sidewalks in the Macao Peninsula are calculated using the CRTN model available in the Department of Transport's Technical Memorandum in the United Kingdom [17]. The input variables for the CRTN model include traffic data (*i.e.*, traffic volume, traffic speed and traffic composition), street configurations (*i.e.*, length, width and orientation of the road), road gradient, road surface nature, and absorbent ground cover. Manual collection of these spatial-related input parameters is a tremendous task which takes time, incurs substantial labor expenditures, and in consequence, may lead to unintentional human errors. Therefore, a prototype urban landscape model has been programmed to integrate the CRTN model with ArcView GIS and hence, automate the noise modeling process. The spatial data required by the CRTN model can be extracted automatically by the urban landscape model from digital maps such as the cadaster map, road network map, green space map, and terrain map. Figure 5 shows several typical maps used in the model system.

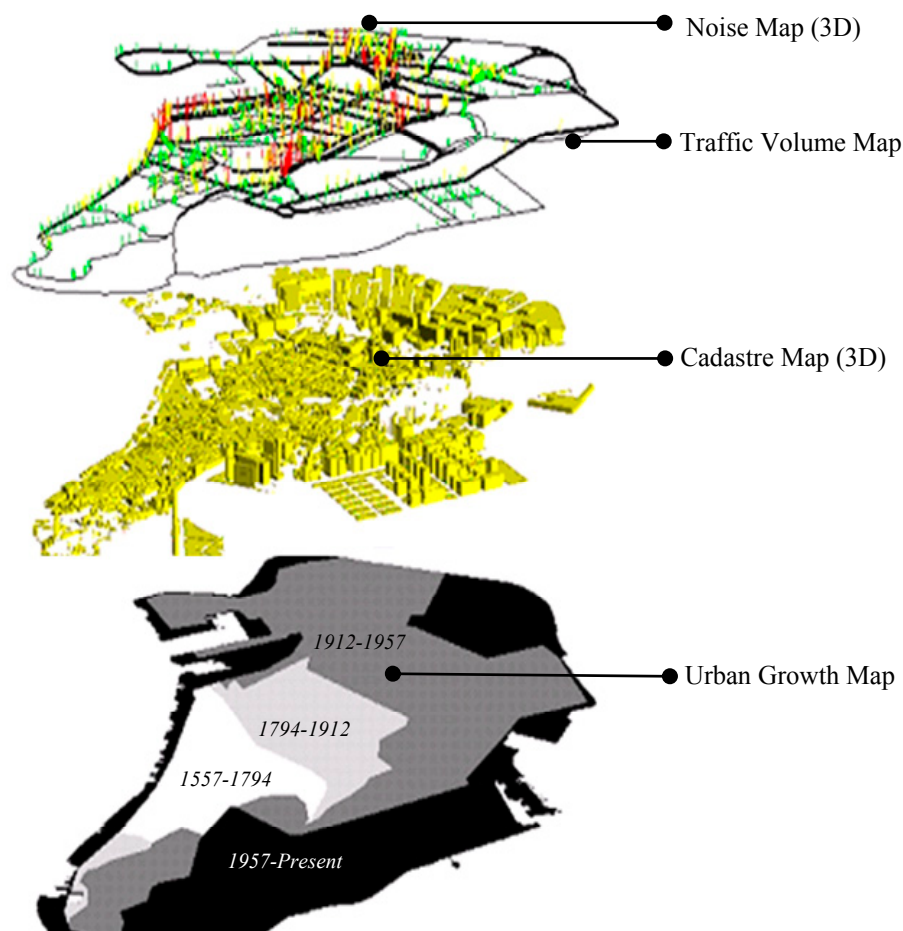


Figure 5. Selected digital maps used by the model system.

When the urban landscape model is executed, a target building is selected from the cadastral map in ArcView. Based on the coordinates of the vertices of the building, the boundary segments of the building are obtained. If the boundary segment faces a road aligning parallel to it, a receptor point will be created in the middle of the sidewalk section between the boundary segment and the roadway. The spatial-related parameters in front of the receptor point are extracted and then input into the CRTN model to simulate the noise pollution at the target receptor point. When all the buildings in the cadastral map are selected and manipulated, the urban landscape model stops the execution. All the modeling results can then be accessed from the receptor point map (*i.e.*, the noise map) in ArcView.

4. Results and Discussion

In this study, acoustic comfort along three cultural and heritage routes in the historic urban area (Urban Areas 1 and 2) is assessed by the Environmental Quality Standard for Noise in China (GB3096-2008) and noise level at roadside should be lower than 70 dB(A) in daytime. Receptor points are created in front of each building façade along both sides of the cultural and heritage routes by the GIS-based traffic noise model system. Pedestrian exposure to traffic noise at each receptor point is estimated based on traffic data obtained by traffic surveys during the evening peak period (17:00–19:00) on working days in 2014. Compared with the traditional method which presents traffic noise in grids at a scale of 0.5 km × 0.5 km, the present work with a higher spatial resolution down to each building can capture more details of acoustic comfort along the cultural and heritage routes.

4.1. Acoustic Comfort along Route 1: Footsteps into the Historic Centre

The Route 1, namely *Footsteps into the Historic Centre*, passes through 16 scenic sites to explore the diverse living activities of the Chinese and the Portuguese in the old days. The activities include healthy ones (e.g., going to theatres and temples) and unhealthy ones (e.g., going to pawnshops, opium houses and red light districts). All cluster in a walking distance of 1.4 km, which takes about 28 min for walking. Of course, tourists may spend more time to enjoy the scenic sites along the route. As described by the government, tourists are “*welcome to experience the charm in this lovely historical city, where two civilisations encounter, and capture every unforgettable moment with your eyes and camera*”.

As shown in Figure 6, the Route 1 starts at the intersection of the New Road (also named Avenida de Almeida Ribeiro) and the avenue Avenida da Praia Grande (Site 1). Overlooking a lake and situated in the southern part of the peninsula, the avenue Avenida da Praia Grande was originally to be the beautiful coastline of the old bay namely Praia Grande (Figure 1), where a number of European commercial houses were built in the 18th century. Tourists are then directed into the New Road and visit the Leal Senado (Loyal Senate), a building for the municipal chamber which has been used since 1784 (Site 2). The word Loyal derives from the title “*City of Our Name of God Macao, There is None More Loyal*” bestowed by the Portuguese King John VI for the ongoing support from Macao after Portugal regained its independence from Spain in 1640.

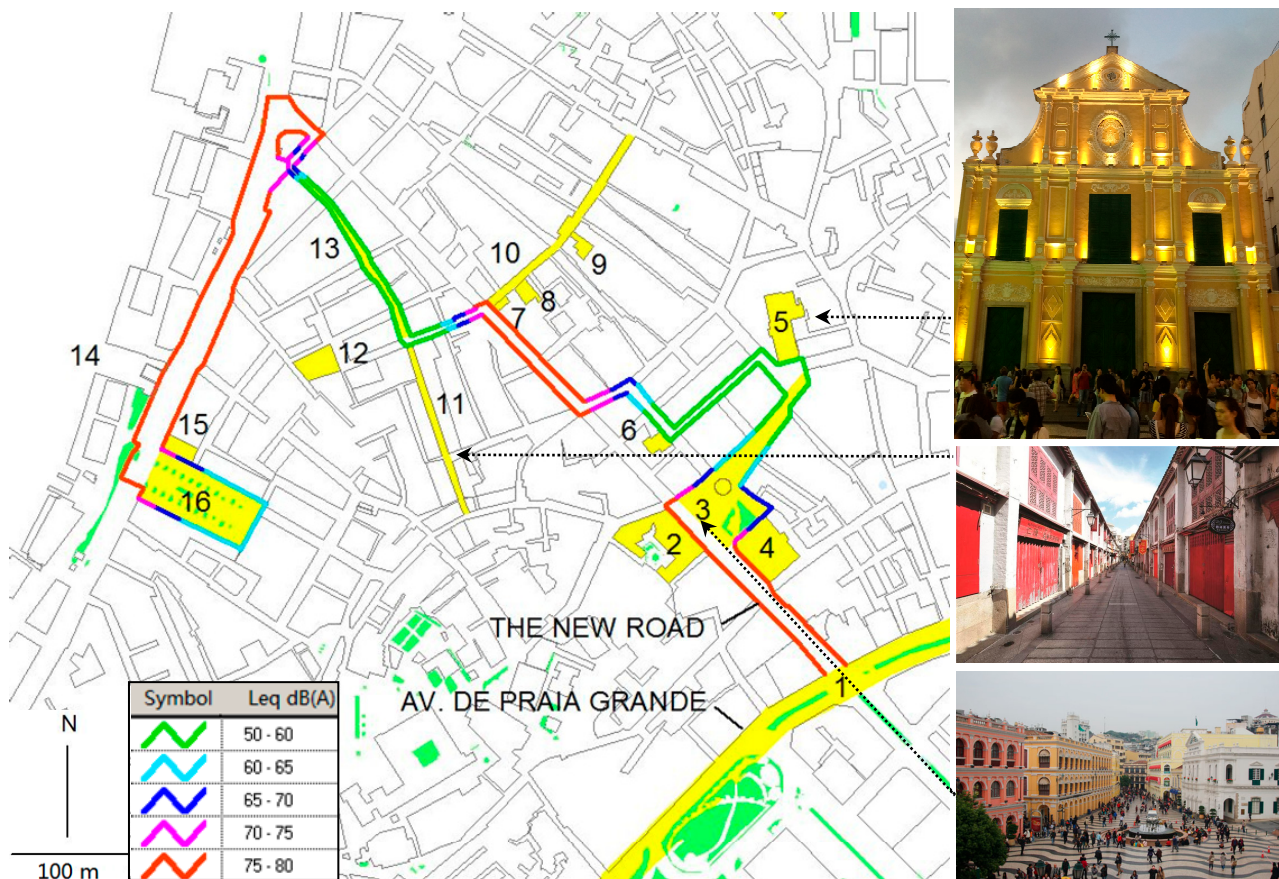


Figure 6. Traffic noise along Route 1 (Site 1, Avenida da Praia Grande; Site 2, Leal Senado Building; Site 3, Senado Square; Site 4, General Post Office Building; Site 5, St Dominic's Church; Site 6, Kuan Tai Temple; Site 7, Heritage Exhibition of a Traditional Pawnshop Business; Site 8, Tung Sin Tong Historical Archive Exhibition Hall; Site 9, Carpentry Guildhall; Site 10, Rua de Camilo Pessanha; Site 11, Happiness Street (Rua da Felicidade); Site 12, Cheng Peng Theatre; Site 13, Rua da Caldeira; Site 14, Inner Harbour; Site 15, Opium House; and Site 16, Praça de Ponte e Horta).

The present study shows that pedestrian exposure to traffic noise between Site 1 and Site 2 along the New Road reaches the highest level of 80 dB(A), which exceeds the national standard by 10 dB(A). The New Road is the longest straight road passing through the heart of the historic area (Urban Area 1) from northwest to southeast. It was designed for vehicle use in the early 1900s. In contrast, the road network in the Urban Area 1 is mostly in a complex curved morphology originally designed for pedestrian transport and human-powered transport such as litters and sedan chairs during 1557–1794, see Figure 6. The complex curvature of the road network and the high percentage of narrow roads limit the traffic speed, traffic capacity, and parking capacity. Today's drivers select the straight New Road rather than the other complex curved roads to pass through the heart of the Urban Area 1. It leads to a significantly higher traffic volume (2700 vehicles/h) and hence, higher pedestrian exposure to traffic noise along the New Road.

Crossing the New Road, tourists are directed to explore the Senado Square (Site 3) and its surrounding architectures, such as the General Post Office Building in the classical style (Site 4) and the St. Dominic's Church built in the late 16th century in the Baroque style (Site 5). In particular, the

church was where the first Portuguese newspaper *A Abelha da China* (The China Bee) was published on Chinese soil on 12 September 1822. Luckily, tourists will feel more comfortable with the acoustic environment (about 58 dB(A)) when they walk deeply into the square towards the northeast and away from the New Road, as the Senado Square and adjacent inner streets on the church side are defined as walking zones.

Tourists will then approach the New Road again to visit a number of historic scenic sites, including Kuan Tai Temple (a chamber of commerce, Site 6), Heritage Exhibition of a Traditional Pawnshop Business (Site 7), Tung Sin Tong Historical Archive Exhibition Hall (Site 8), Carpentry Guildhall (Site 9), Rua de Camilo Pessanha (a street famous for unique technique for production of opium pipe, Site 10), Happiness Street (for prostitution, Site 11), Cheng Peng Theatre (a theatre for Cantonese opera, Site 12), and Rua da Caldeira (a typhoon shelter for boats and ships, Site 13). Except the pawnshop, all are located in the inner streets on both sides of the New Road and therefore traffic noise reduces to 50–60 dB(A), which is lower than the national standard of 70 dB(A).

The final three sites are located on a coastal trunk road which was constructed to cope with the increasing traffic demand along the inner harbor (Site 14) after successive reclamation in 1868, 1923, and 1984. Today, the coastal trunk road also serves as a ring road of the city with significant through traffic, including a number of buses and heavy vehicles, and traffic noise increases to 76–78 dB(A). The harbor was the first one to serve foreign merchant ships in China. In particular, it provided the first and, for a long time, the only wharf dedicated to import opium in the Qing Dynasty. A European-style warehouse to stock opium was built in the late 19th century (Site 15). The wharf was reclaimed to a rectangular plaza (Site 16) after opium was banned in 1946. The traffic noise levels around the plaza are 60–66 dB(A). Tourists will have a comfortable ending when they finally walk into this quite plaza, look at the European-style opium house at the corner, and imagine the busy importing business in this small zone in the late 19th century and its impact on the history of China.

4.2. Acoustic Comfort along Route 2: Crossroads of China and Portugal

The Route 2, namely Crossroads of China and Portugal, passes through eight scenic sites covering historic Portuguese squares and churches, a Chinese temple, a Chinese house, and a maritime museum. The length of the route is 1.6 km and the walking takes about 24 min. As described by the government, “if you take a stroll down the historic path in which two civilisations encounter, you’ll discover the life-long memory and emotions of Portuguese who once called Macau home”.

As shown in Figure 7, the Route 1 starts at the south side of the Senado Square (Site 3) with a high traffic noise of 79 dB(A), which exceeds the national standard by 9 dB(A). The poor acoustic environment is due to its location at the New Road. Considering that the Senado Square is the hottest scenic spot in Macao with good accessibility to bus services, it is understandable for the government to start the journey here. Thereafter, the journey turns up to the hills to explore the earliest main street in Macao. Tourists will experience the diverse worship culture where East meets West, when passing through the Portuguese St. Augustine’s Square (Site 17), St. Joseph’s Seminary and Church (Site 18), and St. Lawrence’s Church (Site 19), and then walking down to the Chinese A-Ma Temple (Site 22) at the coast. While the Portuguese churches poised on the hills overlooked the urban and coastal areas, the Chinese temple was built along the coast to protect the fishermen. As in hilly areas, the traffic volume

reduces significantly to about 350 vehicles/hour and thus the traffic noise drops about 10 dB(A) to 66–69 dB(A), which meets the national standard of 70 dB(A). Therefore, tourists can enjoy a better acoustic environment to imagine how the Portuguese gathered on the front steps of the church at Site 19, overlooked the sea, and prayed for the safe return of sailors; and how the Chinese fishermen entered the temple at Site 22 and worshipped their god for safety on the foot of the hill. Between Site 19 and Site 22, tourists will find the home of a famous Chinese literary figure (Site 20) and the square where the earliest Portuguese lived (Site 21), see Figure 7. Finally, a maritime museum (Site 23) at the coast will help tourists to conclude the impact of maritime activities on the earliest development of Macao. Tourists will enjoy the best acoustic environment with traffic noise of 60–64 dB(A) at Site 22 and Site 23 situated in a plaza facing the sea.

In short, when tourists start their journey at Site 3, they may feel uncomfortable with the exposure to higher traffic noise level of 79 dB(A). The acoustic environment will be improved significantly on the rest of the journey as tourists walk pass the churches and temples along the Route 2. The traffic noise levels drop to 66–69 dB(A) at Sites 17 to 20 and further drop to 60–64 dB(A) at Sites 21 to 23.

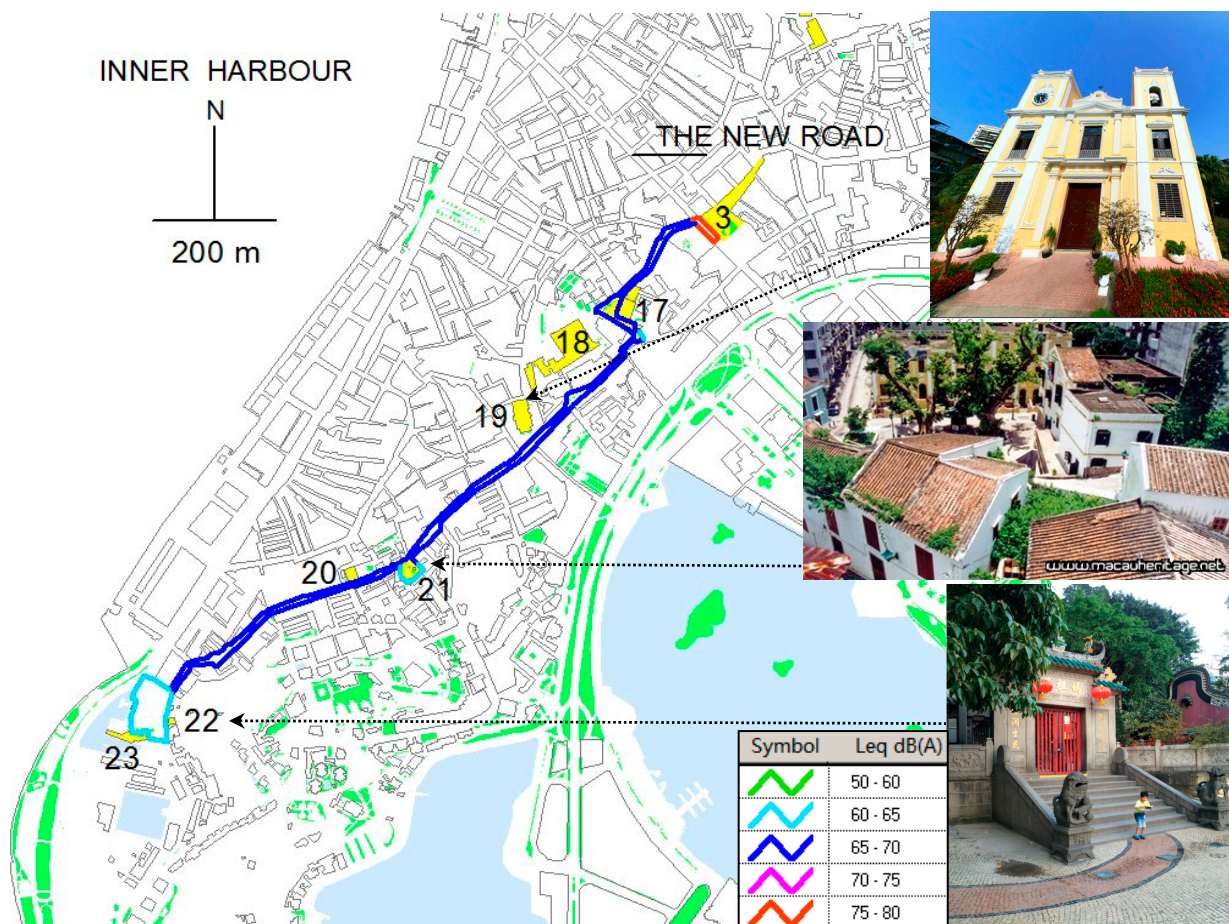


Figure 7. Traffic noise along Route 2 (Site 3, Senado Square; Site 17, St. Augustine's Square; Site 18, St. Joseph's Seminary and Church; Site 19, St. Lawrence's Church; Site 20, Mandarin's House; Site 21, Lilau Square; Site 22, A-Ma Temple; and Site 23, Maritime Museum).

4.3. Acoustic Comfort along Route 3: Marriage of East and West in St. Anthony's Parish

The Route 3, namely *The Marriage of East and West in St. Anthony's Parish*, has 19 scenic sites covering a section of the old city wall and the adjacent Portuguese and Chinese architectures outside the city wall. The route is located in the St. Anthony's Parish which has been developed since the first expansion of the old Portuguese enclave in the late 18th century. The length of the route is 2 km and the walking takes about 41 min. Tourists may “*experience a special romance in this lovely multicultural vicinity where you'll see beautiful urban space with charming Portuguese and Chinese buildings and their enchanting stories*”, as suggested by the government.

As shown in Figure 8, the Route 3 starts at Ruins of St. Paul's (Site 24), a must visit for all the tourists to Macao. The façade of the St. Paul's Church, which was constructed in 1644 and left after a fire in 1835, has been acknowledged as a perfect fusion of western and eastern cultures. The façade is situated in front of the gate of the Old City Wall (Site 25). A Chinese temple (Sites 26 and 27) built just a few steps away is always considered as a symbol of two diverse cultures coexisting in harmony. Tourists can enjoy good acoustic environment with noise level of 50–60 dB(A) in these sites as they are on the top of a hill and adjacent to pedestrian zones.

Tourists will then walk along a quite historic cobble street to visit a residential area rich in historical and cultural context (Sites 28 to 30). Once situated on a forested hillside, the cobble street has less traffic and hence a comfortable acoustic environment with noise levels of 65 dB(A). At the end of the street, tourists will find one of the oldest churches (Site 31). Traffic noise increases significantly to 74 dB(A) as the church faces a busy trunk road connecting the east and west sides of the city. Nevertheless, traffic noise decreases gradually to 54–58 dB(A) when tourists cross the busy trunk road and enter a garden (Site 32) to visit a historic Portuguese house (Site 33) and a Protestant cemetery (Site 34) related to activities of the British East India Company. As a legacy prior to the UK's occupation of Hong Kong, the cemetery provides a comprehensive record of the earliest Protestant community from US, UK and Portugal, including the author and translator of the first Chinese–English Dictionary and Chinese Bible. Tourists will find a peaceful environment in the garden and the cemetery.

Thereafter, tourists are directed to explore the rest eight sites (Sites 35 to 42) situated in a traditional Chinese residential area developed in 1794–1912 (*i.e.*, Urban Area 2). Traffic noise at Sites 35–38 increases to 72–74 dB(A) along the aforementioned busy trunk road connecting the east and west sides of the city. Tourists then walk into a road network where roads radiate outwards from important sites, and this results in a triangular or trapezoid layout of small pieces of building blocks which restrict traffic volume and speed (see Figure 8). Traffic noise decreases slightly to 71 dB(A) at Site 39 (a historic temple) and Site 40 (a garden that was a “parking area” for human-powered transport such as litters and sedan chairs in front of the temple). With a sharp turn, tourists are directed to visit a historic western roundabout (Site 41) and home of a Chinese general (Site 42) with traffic noise of 67 dB(A) and 69 dB(A), respectively.

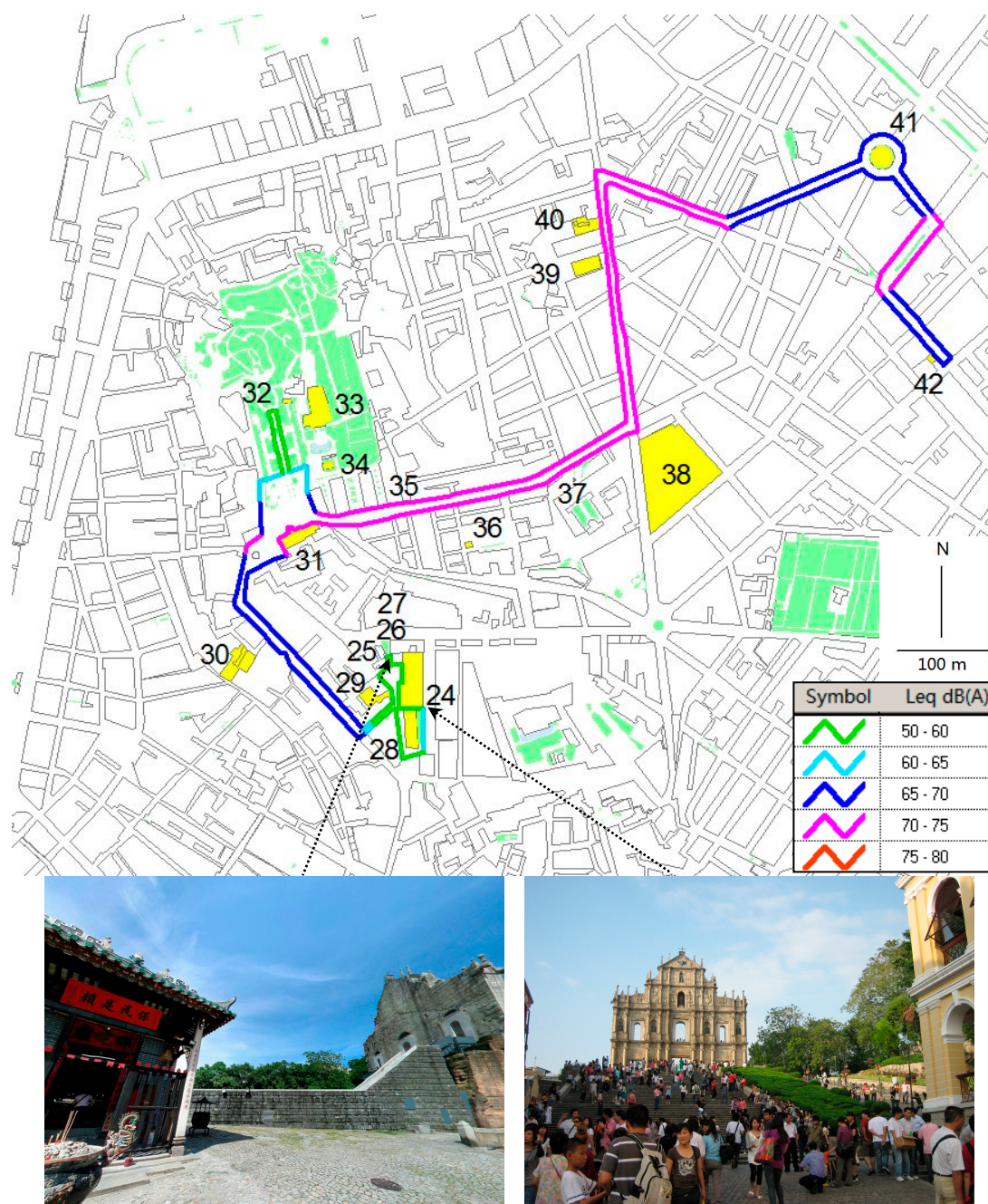


Figure 8. Traffic noise along Route 3 (Site 24, Ruins of St. Paul's; Site 25, Section of Old City Wall; Site 26, Na Tcha Temple; Site 27, Na Tcha Exhibition Hall; Site 28, Travessa da Paixão; Site 29, Ho's Clan Association; Site 30, Pátio da Eterna Felicidade; Site 31, St. Anthony's Church; Site 32, Camões Garden; Site 33, Casa Garden; Site 34, Protestant Cemetery; Site 35, Tou Tei Temple in Sam Pa Mun; Site 36, Pao Kong Temple and Temple of Divinity of Medicine; Site 37, Statue of Dr. Sun Yat Sen; Site 38, Fire Services Museum; Site 39, Lin Kai Temple; Site 40, San Kio Garden; Site 41, Rotunda de Carlos da Maia; and Site 42, Ye Ting Residence).

5. Conclusions

Visualization of acoustic comfort along the three cultural and heritage routes in the Macao Peninsula shows that all the tourist routes suffer from excessive traffic noise at certain sites. In Route 1, namely *Footsteps into the Historic Centre*, traffic noise between the first two sites along a busy road reaches the highest level of 80 dB(A), which exceeds the national standard by 10 dB(A). In Route 2, namely *Crossroads of China and Portugal*, the starting point at the south side of the Senado Square also has a high traffic noise of 79 dB(A). In Route 3, namely *The Marriage of East and West in St. Anthony's Parish*, 11 out of the 19 sites have noise levels over the national standard. The adverse acoustic environment will surely have negative impact on the promotion of route-based tourism in the long run.

Fortunately, the Macao government is considering a number of measures such as higher import tax and higher parking fee against the rapid increase of private vehicles. A light rail system is also under construction to reduce pressure on road transport. It will be interesting to see whether traffic flow and traffic noise could be reduced accordingly. The severe traffic noise pollution problem has also urged the development of electric vehicles in Macao in recent years. The features of electric vehicles including zero-emission and low noise level provide the promising potential to alleviate the severe traffic-related pollution. Nevertheless, in considering that the total land area of the Macao Peninsula is only 9.3 km² and the population density reaches 53,400 inhabitants/km², local residents should be encouraged to walk more in daily life to reduce excessive vehicles and thus traffic noise in this tiny but highly compact city.

Spatial analysis of acoustic comfort along the cultural and heritage routes shows that urban growth affects urban form and street layout, which in turn affect traffic flow and acoustic comfort in urban area. Decision makers need to consider the interaction of these effects in urban planning, transport planning and tourism planning. In particular, as demonstrated in this study, spatial techniques to visualize acoustic comfort are foreseen to be used more frequently to support effective tourism planning in the future.

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Author Contributions

Both authors have equal contribution to this paper, and have read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

References

1. King, V.T. Culture, heritage and tourism in Southeast Asia. *Pertanika J. Soc. Sci. Humanit.* **2012**, *20*, 5–7.
2. Hitchcock, M.; King, V.T.; Parnwell, M. *Heritage Tourism in Southeast Asia*; NIAS Press: Copenhagen, Denmark, 2010.
3. UNESCO. Culture. Available online: <http://www.unesco.org/new/en/cairo/culture/> (accessed on 30 July 2015).
4. Murray, M.; Graham, B. Exploring the dialectics of route-based tourism: The Camino de Santiago. *Tour. Manag.* **1997**, *18*, 513–524.
5. Briedenhann, J.; Wickens, E. Tourism routes as a tool for the economic development of rural areas—Vibrant hope or impossible dream? *Tour. Manag.* **2004**, *25*, 71–79.
6. Meyer, D. *Tourism Routes and Gateways: Key Issues for the Development of Tourism Routes and Gateways and Their Potential for Pro-Poor Tourism*; Overseas Development Institute: London, UK, 2004.
7. Capp, S. *The European Institute of Cultural Routes*; Council of Europe: Strasbourg, France, 2002. Available online: http://www.arcchip.cz/w02/w02_capp.pdf (accessed on 23 January 2015).
8. Zheng, M.C. The design of a map for tourists to engage in circuitous movements. *J. Asian Archit. Build. Eng.* **2014**, *13*, 601–607.
9. Garau, C. From territory to smartphone: Smart fruition of cultural heritage for dynamic tourism development. *Plan. Pract. Res.* **2014**, *29*, 238–255.
10. Garau, C.; Ilardi, E. The “Non-Places” meet the “Places:” Virtual tours on smartphones for the enhancement of cultural heritage. *J. Urban Technol.* **2014**, *21*, 79–91.
11. Garau, C. Perspectives on cultural and sustainable rural tourism in a smart region: The case study of Marmilla in Sardinia (Italy). *Sustainability* **2015**, *7*, 6412–6434.
12. Ghadirian, P.; Bishop, I.D. Integration of augmented reality and GIS: A new approach to realistic landscape visualization. *Landsc. Urban Plan.* **2008**, *86*, 226–232.
13. Scolozzi, R.; Schirpke, U.; Detassis, C.; Abdullah, S.; Gretter, A. Mapping alpine landscape values and related threats as perceived by tourists. *Landsc. Res.* **2015**, *40*, 451–465.
14. United States Environmental Protection Agency. *Noise Effects Handbook: A Desk Reference to Health and Welfare Effects of Noise*; EPA 550-9-82-106; National Association of Noise Control Officials: West Windsor, NJ, USA, 1981.
15. Anderson, G.S.; Menge, C.W.; Rossano, C.F.; Armstrong, R.E.; Ronning, S.A.; Fleming, G.G.; Lee, C.S.Y. FHWA traffic noise model, version 1.0: Introduction to its capacities and screen components. *Wall J.* **1996**, *22*, 14–17.
16. Tachibana, H.; Sasaki, M. ASJ prediction methods of road traffic noise. In Proceedings of the Inter-Noise, Yokohama, Japan, 29–31 August 1994; pp. 283–288.
17. Department of Transport. *Calculation of Road Traffic Noise*; Department of Transport, Welsh Office, HMSO: London, UK, 1988.
18. RLS-90. *Richtlinien für den Lärmschutz an Straßen*; Der Bundesminister für Verkehr: Bonn, Germany, 1990.

19. Moragues, A.; Alcaide, T. The use of geographical information system to access the effect of traffic pollution. *Sci. Total Environ.* **1996**, *189/190*, 267–273.
20. Li, B.; Tao, S.; Dawson, R.W.; Cao, J.; Lam, K. A GIS based road traffic noise prediction model. *Appl. Acoust.* **2002**, *63*, 679–691.
21. Brown, A.L.; Affum, J.K. A GIS-based environmental modeling system for transportation planners. *Comput. Environ. Urban Syst.* **2002**, *26*, 577–590.
22. Pamanikabud, P.; Tansatcha, M. Geographical information system for traffic noise analysis and forecasting with the appearance of barriers. *Environ. Model. Softw.* **2003**, *18*, 959–973.
23. Sheng, N.; Tang, U.W. Spatial analysis of urban form and pedestrian exposure to traffic noise. *Int. J. Environ. Res. Public Health* **2011**, *8*, 1977–1990.
24. Tang, U.W.; Wang, Z.S. Influences of urban forms on traffic-induced noise and air pollution: Results from a modelling system. *Environ. Model. Softw.* **2007**, *22*, 1750–1764.
25. Best Travel in 2015 No.10 Macau. Lonely Planet. Available online: <http://www.lonelyplanet.com/best-in-travel/regions/10-macau?detail=1> (accessed on 23 January 2015).
26. Câmara Municipal de Macau Provisória. *Overlooking the Earth: Map of China and Macao*; Municipal Council of Macao: Macao, China, 2001; p. 14.
27. Tang, U.W.; Sheng, N. Macao. *Cities* **2009**, *26*, 220–231.
28. DSEC. *Yearbook of Statistics 2014*; Statistics and Census Service, Macao SAR Government: Macao, China, 2014.
29. Duncan, C. Macau. *Cities* **1986**, *3*, 2–11.
30. UNESCO World Heritage Centre. Historic Centre of Macao. Available online: <http://whc.unesco.org/en/list/1110> (accessed on 23 January 2015).
31. CNN. Casinos Beat the Banker: Macau Leapfrogs Switzerland in Wealth Chart. Available online: <http://edition.cnn.com/2014/07/02/business/macaucasinoworldcup/> (accessed on 27 January 2015).