The 3D noise mapping for Pearl River New Town of Guangzhou

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ABSTRACT

Noise mapping has been recognised as a useful tool for city noise planning and management but 2D noise maps have limitations on determining and visualizing noise impact in urban areas. For more in-depth study of the urban road traffic noise distribution on the façade of the buildings, the main goal of this study is to develop a 3D noise map for the Pearl River New Town of Guangzhou. To achieve this goal, Greenberg’s traffic flow model was used and combined with the GPS data that collected by floating cars to obtain the traffic flow data for the calculation of traffic noise emission. And then, the geographical data were automatically extracted from GIS to provide the geographical information to calculate the traffic noise attenuation. Finally, using the 3D traffic noise predict model, the 3D noise map of the Pearl River New Town was created.

Keywords: Road traffic noise, 3D noise mapping, GIS, GPS

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1. INTRODUCTION

Nowadays, traffic noise has become an omnipresent factor affecting the people's psychosomatic health and causing some serious diseases. Over the years, there have been many studies focus on assessing the harm of noise on humans and investigating the relationship between the environmental noise and various diseases, such as myocardial infarction (1,2) and hypertension (3,4).

Noise mapping has been recognised as a useful tool for city noise planning and management. And the DG Environment of the European Commission, who is preparing a Directive on Environmental Noise to provide standardized methods for noise mapping to assess and control noise pollution (5). 2D noise map has been widely used in assessing environmental noise impact. However, it can be expected that a 3D noise map can provide much more information and more accurate analysis when 3D effects are relevant, such as in an urban area. Therefore, some recent studies used 3D noise map to assess the effectiveness of noise barriers (6,7) and determine the exposure of the urban population to road traffic noise (8,9).

The main goal of this research is to develop a 3D noise maps for the Pearl River New Town of Guangzhou to study the urban road traffic noise distribution on the façade of the buildings in this area. In this research, the Global Positioning System data of floating cars in Guangzhou city would be used to derive the urban road traffic flow data, which would be combined with the traffic noise prediction model to calculate the traffic noise emission. And the geographical data would be extracted from the ArcGIS map to provide the necessary information to calculate the noise attenuation.

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2. METHODOLOGY

2.1 Data Collection

2.1.1 Traffic Flow Data

For an urban road traffic noise map, traffic speed and traffic volume of light, medium and heavy vehicles should be collected to calculate noise value. But collecting and processing of the data needed to produce a noise map is such a difficult and expensive work. Maybe the speed limit of each road section from traffic signs or steady-speed traffic flow assumption based on experience can be used to produce a noise map, but the accuracy and reliability of that noise map could be low and is not suitable for further analysis.

To obtain the traffic flow information in a large city, this study used the GPS data of floating cars, which were came from the GPS locators installed in the taxis. Although many advanced traffic flow models were proposed to acquire more accurate outcomes, they are too complicated and hardly to fetch the entire model’s parameters to estimate the traffic flow data for a large area. Three simple traffic flow models will be considered in this study, the Greenshields’ model (10), the Underwood’s model (11) and the Greenberg’s model (12):

\[ Q = k_j (v - \frac{v^2}{v_f}) \]  \hspace{1cm} (1)

\[ Q = -\frac{k_j}{2} \ln \frac{v}{v_f} \]  \hspace{1cm} (2)

\[ Q = \frac{v k_j}{\frac{v^2}{e^{v/v_f}}} \]  \hspace{1cm} (3)

where \( Q \) is the traffic volume (veh/h), \( v \) is the vehicle speed (km/h), \( v_f \) is the free-flow speed (km/h), and \( k_j \) is the jam density (veh/km).

Since the Pearl River New Town has a high traffic density in the road network and according to the comparison of the three traffic flow models, the Greenberg’s model was chosen to estimate the traffic flow data for the study area in this research.

Every single GPS data used in the study contains the attributes such as time, the car’s speed, the car’s attributes, and the ID of the road the car was driving on. To estimate the traffic flow data from the Greenberg’s traffic flow model, three parameters (\( v, v_f \) and \( k_j \)) should be determined. For a road section, the average velocity of the floating cars (parameter \( v \)) in a certain period of time (such as an hour) is calculated as the space mean speed of that road section. The last two parameters, \( v_f \) and \( k_j \), can be acquired from the historical monitoring data of the traffic flow of that city.

2.1.2 Geographical Data

To obtain the geographical data such as the roads and buildings to calculate the noise attenuation, this research used the controls and interfaces in ArcGIS Engine to acquire the necessary geographical data from the ArcGIS map of Guangzhou. To achieve this goal, a spatial filter and geometry inquiry requirements, which are used to select the necessary elements in the defined layer, were developed. Finally, an attribute table, which mainly contains the road ID, road name, coordinates of the endpoints of road sections, building ID, building name and coordinates of the outlines of the buildings, will be generated. Figure 1 is an example of the road attributes table. These geographical data extracted from the ArcGIS map of Guangzhou can be used to combine with the noise attenuation model to calculate the traffic noise attenuation.
2.2 The Calculation of 3D Noise Map

For the urban road traffic noise calculation, the FHWA highway traffic noise prediction model (13) will be applied in this study. The following formula was used to calculate the equivalent sound level of vehicle type \( i \) at a distance \( r \) away from the driving line:

\[
L_{eqi} = L_{eqi0} + 10 \log \left( \frac{N_i}{N_j} \right) + \Delta L_d + \Delta L_h + \Delta L_{other} - 16
\]

(4)

where \( L_{eqi} \) is hourly equivalent sound level of the \( i \)th class of vehicles, \( L_{eqi0} \) is the average noise emission level of vehicle type \( i \) at a reference distance (7.5 m), \( \Delta L_d \), \( \Delta L_h \) and \( \Delta L_{other} \) is the distance attenuation, the attenuation from buildings and the attenuation from other factors, respectively.

\( \Delta L_h \) is an important factor of noise attenuation in an urban area and should not be ignored. In the ISO 9613-2 1996 (14), the calculation of the noise attenuation from buildings is as follows:

\[
\Delta L_h = A_{h,1} + A_{h,2}
\]

\[
A_{h,1} = 0.1 \frac{S_{bu}}{d_b} \left( P \right)
\]

(5)

where \( S_{bu} \) and \( L \) is the building area and the total area respectively, as shown in Figure 2. \( d_b \) is the length of that noise propagation path, \( P \) (which is \( \leq 90\% \)) is the percentage of the projected length of the building facades relative to the total length of the road near the buildings.
on noise attenuation from the height of the buildings. To consider the three-dimensional case, the application scenario of that formula was extended in this paper to calculate the attenuation of 3D buildings. Based on the formula (5), the formula to calculate the 3D noise attenuation from buildings is as follows:

\[
\Delta L_b = A_{hous,1} + A_{hous,2} \\
A_{hous,1} = 0.1 \frac{V'}{V} d_b \\
A_{hous,2} = -10 \log \left(1 - \left(\frac{q}{100}\right)\right)
\]

It can be seen that, the ratio of the area \( \frac{S_{hi}}{S} \) was replaced by the ratio of the volume in the calculation of the item \( A_{hous,1} \). And the \( p \) was replaced by the \( q \), which represents the percentage of the projected area of the building façade relative to the total area of the vertical plane rising from the roadside near to the building façade. The formula (6) was used in this research to calculate the 3D noise attenuation of the buildings.

3. 3D NOISE MAP OF PEARL RIVER NEW TOWN

Pearl River New Town has an area of 5.25 km² in Guangzhou, China, and its east-west direction spans approximately 2100 m, while the north-south direction spans approximately 2500 m. There are approximately 445 straight sections in this area. Every straight section has several lanes, and each lane can be seen as a line source and there are approximately 2856 line sources here. About 1085 buildings to be counted in Pearl River New Town, and there are 446367 noise receiver points on building facades with the grid step of 4 m.

The methods mentioned above will be used to produce a 3D noise map for the Pearl River New Town to study the urban road traffic noise distribution. This research focuses on the noise distribution on the surface of buildings because it impacts city residents the most. In addition, with the difficulty of collecting all the geographical data in such a large area, only the roads and buildings are included.

The noise pollution impacts people the most at night time, so the 3D noise map at 23:00 of the study area was created. Figure 3 is an aerial view of the 3D noise map of Pearl River New Town. Form this noise map, road traffic noise distribution on each facades of building can be easily observed. An observed point located at a building façade near the Sport East Road, shown as the Figure 4, was selected to analyze the sound level pressure. In this case, the Sport East Road is a minor arterial road with the traffic volume 887.688 pcu/h and the average vehicle speed 36.563 km/h, and the noise value of that observed point is 55.45 dB. This noise value exceeds the legal limit value 50 dB and affects sharply the people’s sleep, some noise mitigation measures should be performed to prevent people from the disturbance of noise pollution.
4. CONCLUSIONS

A 3D noise map was developed for the Pearl River New Town to study the road traffic noise distribution on the façade of the buildings. The Greenberg’s traffic flow model was used to estimate the traffic flow data of the road network in the Pearl River New Town from the GPS data collected by the floating car. To obtain the geographical data for the calculation of the noise attenuation, a method was proposed to extract the geographical information from the ArcGIS map of Guangzhou. The 3D attenuation effect of urban buildings was also taken into account to reveal the 3D noise distribution in an urban area.

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