

Application of Noise Mapping in Environmental Noise Management in Hangzhou, China

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Summary

Noise mapping is an emerging technology of urban noise management, which developed first and widely applied in the European Union. Researches on noise mapping in China have been gradually developed today. Hangzhou has become the leading city in China which has tried to use the noise map to conduct urban noise management. Noise map of two administrative areas, based on the local noise prediction models, have been drawn in Hangzhou noise management platform. The noise map can be displayed in 2D and 3D on the platform and be updated dynamically by multisource monitored data and parallel computing technology. Meanwhile, the statistical analysis of evaluation results, like over proof buildings, impacted population can be provided. Based on noise map, the main urban noise sources, including traffic noise and construction noise can be monitored, evaluated, compared, and finally improved in the platform. The noise map makes it more scientifically and efficiently for noise pollution management in Hangzhou.

1. Introduction

Noise mapping technology was first proposed in Europe more than ten years ago. As noise map can supply a scientific and efficient view of city noise distribution, it can help for the urban planning and environmental protection. According to EU Directive 2002/49/EC, the member states need to draw noise map of main areas, and update after five years. They also should set up the associated action plans according to the noise map. Up to now, each member state has drawn their noise map. According to the noise map, a variety of scientific and effective action plans have been implemented^[1-3]. Noise map application in China is still in its infancy. Some cities, such as Hong Kong, Beijing and Hangzhou are in the forefront of this field. As there are many tall buildings in these cities, noise maps often include 3D view as well as 2D view. Meanwhile there are pilot efforts that applied noise map in urban noise management in these cities. Hangzhou noise management platform is an example of the application of the noise map technology on urban noise management^[4-6].

Hangzhou is one of experimental cities of the National wisdom city project. Where new techniques of Internet of things, cloud computing

and intelligent terminal is advocated and encouraged. Based on the high level basic conditions, noise map in Hangzhou adopted some new ideas of these techniques and now becomes part of the “wisdom city”. Hangzhou noise map covers an area of two boroughs: Shangcheng District and Xiacheng District, with a total area of 50 square kilometers. Hangzhou noise management platform combines information of road traffic, buildings, population, functional areas and regional noise monitoring. It can provide 2D and 3D noise maps simultaneously and display the relevant information in the area intuitively and comprehensively. The platform used advanced hardware and software, and merged the noise automatic monitoring technology and noise prediction technology, to updating the noise map dynamically. The platform combines noise automatic monitoring, trend forecasting and quality management of noise together. This can support proposing management countermeasures of noise monitoring, controlling and planning.

2. System Architecture

The noise Management Platform of Hangzhou consists of three main functions: database, computing and information publishing. Database provides data which is needed by computing and

publishing platform, like GIS data, sound sources data, measure data, and stores the results data and user data created by computing and publishing platform. Computing platform is based on new-developed noise map prediction software, and integrates local road traffic noise prediction model of Hangzhou in the calculation to improve the prediction accuracy. Information publishing platform is the primary window of the platform to users. It contains nine major functions: publishing noise map, building information management, information display of functional areas and so on. The architecture of the platform is shown in Figure 1.

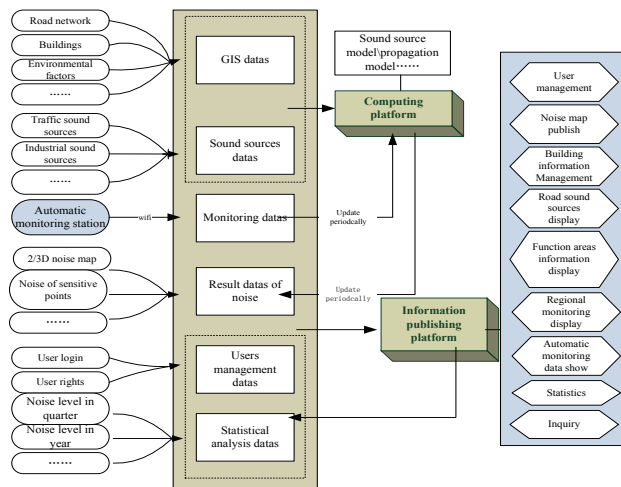


Fig.1 System Architecture Diagram of Noise Management Platform

3. Main work of system establish

3.1 Data acquisition

The basic data related to noise map in the system can be divided into three categories. The first is the sound source data, such as road, airport, factory, and so on. The second is GIS data, such as road networks, buildings, population distribution. The third is other measurement data, such as noise monitoring sites data, weather information.

According to Hangzhou city noise mapping project, the major traffic noise source in the project study area are determined. It includes 10 expressways, 27 trunk roads, 88 secondary roads and a lot of branch roads. Through measuring the noise and traffic simultaneously, the traffic flow, vehicle speed and vehicle ratio of the typical roads in different periods is determined. These original data were imported to system to calculate noise map. The roads not monitored are treated as the monitored road of the same grade.

As the urban construction and development is very fast in Chinese cities. The difference between

the original GIS data and the reality in the selected region is unavoidable. Therefore it needs to assess the accuracy of the original data before calculating noise distribution and make suitable amendments. The GIS data was updated to match the reality by manual measurement. After this procedure, there are 19817 buildings, 352 road sound sources with the total 370km, 40 sound barriers with the total 10.5km and the railway with the total 56km in the study area. Information of population distribution and traffic are stored as character of buildings and roads respectively.

Because it needs to update noise maps dynamically and analyze after first drawing, the database also contains the sound functional areas, measuring points and other necessary information.

3.2 Local noise prediction model

The roads of Hangzhou are mainly comprised of expressway, trunk road and secondary trunk road, which provide main contribution of the noise to the city. To ensure the accuracy of noise map, a local road traffic noise prediction model is built according to the actual state of Hangzhou traffic noise in this project. The model uses the basic forms of popular road traffic noise prediction model, which gives the relation between the predicted points and traffic parameters. It relates the results of roads traffic noise with measured vehicle sound sources and traffic flow with some characteristic parameters. And the parameters can be determined by numerical fitting of measured data. So the road traffic noise prediction model was established and then used to draw the city noise map of Hangzhou. The basic expression of typical road traffic noise source is:

$$L = A_1 + A_2 \times lg^{Q_c} + A_3 \times lg^{V_c} + A_4 \times lg^{D_0/D}$$

Among them: A_1 , A_2 , A_3 , A_4 are constants, determined by the measured data. Q_c is the equivalent traffic flow. V_c is the equivalent average speed. D_0 is the reference distance, $D_0 = 7.5m$. D is the distance between the prediction point and the road.

According to the survey, the roads in Hangzhou are mainly asphalt pavement. And the vehicles can be divided into two classes: light vehicles and heavy vehicles (buses). The speed of the vehicles is often slow. The light vehicles is mainly between the speed of 20~60km/h, the heavy vehicle is mainly between 20~55km/h. The vehicle class and speed are the two key factors in the measurement. The survey time is selected during 7:00 to 11:00 am, 14:00 to 17:00 pm and 19:00 to 22:00 pm of the workday, in order to get

different vehicle running conditions. Some straight roads with light traffic flow is selected to measure the vehicle pass-by noise L_{Aeq} . The measurement points are 7.5m apart from the outside lanes of road and 1.5m height above the ground. The specific value of A_1 , A_2 , A_3 , A_4 is finally determined through statistical analysis.

Tab.1 The parameter selection table for the road traffic noise prediction model of Hangzhou

Influencing factors	Basic formula	Variable value	Instructions
Vehicles sound source model	$L_{ref} = A_1 + A_3 \times lg^{Vc}$	small: $A_1 = 22.8, A_3 = 27.0$	Application of speed range: 20~60km/h
		large: $A_1 = 20.0, A_3 = 35.8$	
Correction by flow	$A_2 \times lg^{Qc}$	trunk road: $A_2 = 4.5$	--
		secondary trunk: $A_2 = 4.8$	
Correction by speed	$\Delta D = A_4 \times lg^{D_0/D}$	$A_4 = 20$	The road is disserted into point sound sources, the geometric attenuation law reference the point source.

3.3 Noise mapping calculation

The current common noise prediction software in China mainly comes from EU countries, which are based on the prediction standard or model of EU countries. Those standards may be quite different from Chinese standards. So the noise prediction software - SwallowSound is used in this project. The software is developed by Beijing Municipal Institute of Labour Protection, and the prediction model is based on Chinese standard and revised by measured data of the traffic noise in Hangzhou.

Noise map update system mainly includes automatic monitoring equipment, dynamic management platform and database software. The data from the automatic monitoring equipment is obtained periodically through the control by the dynamic management platform. After some statistical analysis, the real-time data is stored in the database. The database provides data support for updating the noise map dynamically. The

multisource noise monitoring data is analyzed in dynamic update system, which can calculate the new noise map by revising technology with necessary quality.

Automatic measurement points in this project can be divided into three types. They are road measurement points, regional measurement points and functional area measurement points. There are seven automatic road measurement points. As long-term measurement stations, they provide the main data for noise map updating. The measurement of regional points and functional area points provide temporary measurement data, which are mainly used to amend noise map errors.

3.4 Information releasing platform

The information releasing platform provides website interface. It is mainly used to release noise map, analysis noise pollution problem, evaluate noise level and so on. The system is a comprehensive environmental management and publishing platform. It includes modules that show geographical information, noise measurement information and environment noise information and other data. It can not only show the acoustic environmental quality status directly, but also provide the function of locating, querying and statistical analyzing. The system mainly consists of six subsystems or modules. They are the user information subsystem, information retrieval subsystem, noise statistics subsystem, database management subsystem, spatial analysis subsystem, reporting subsystem. These subsystems provide a great convenience to manage and control the noise pollution of Hangzhou.

4. Application of the noise management platform

4.1 View of city noise distribution

Noise map combines the noise level and urban geographic information, which provides the noise distribution comprehensively and intuitively to the city manager. It helps to develop scientific and reasonable noise reduction measures to the area where the noise pollution is serious. As the city managers must consider the noise influence when proposing city planning, the organic combination of noise information and geographic information makes it more efficient. Hangzhou city noise map is drawn by local traffic model, while the geographic information it used matches the present traffic condition of the city. It makes the noise evaluation of city planning more efficient and meaningful.

Besides showing the conventional noise map,

the noise management platform also provides subtraction of noise map between different periods, and shows the change of the noise in different periods as a graph. It can also display the changing map of the same area in different periods by subtracting some period of noise map from another. Through the changing map, managers can find the area where the noise changed obviously and be targeted to analyze the influence, such as vehicle flow changed, road reconstruction, or other planning activities. And then it can guide the planning activities in other areas of the city, in order to reduce the increasing noise pollution behavior or increase the behavior which can improve the noise environment.

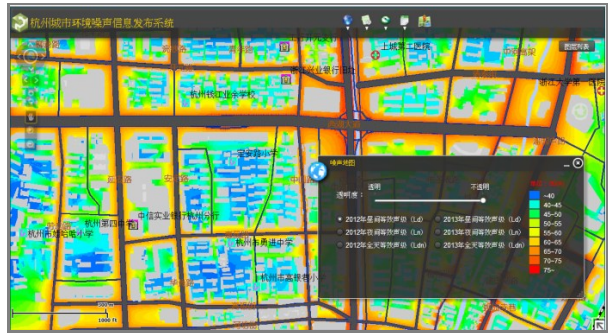


Fig.2 Noise Map Published Platform

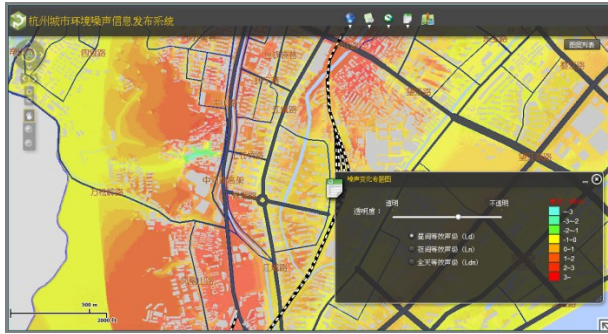


Fig.3 Difference Noise Map

4.2 Management of noise functional area

The noise management platform also gives a view of the distribution of different noise functional areas in Hangzhou. The noise functional area is proposed in the standards named “noise environmental quality” of China, in which the city is divided into different grade areas according to the usage of the area. Different area needs different noise environmental quality. The noise of different area shall be controlled under different limit, which makes the noise management more reasonable. Beside of the noise map, the platform can also give a view of the regions which exceed its standard noise limit in different functional areas, and these regions are the key areas need to be faced. At the same time, the area where the noise level is near the standard limit value need to be noticed in city

planning and paid more attention when assessing the noise impact.

4.3 Management of noise exposure

The management of noise pollution should keep the human-centered principle. So in the use of noise maps for urban management, the population of noise exposure is considered. The regions where the noise level is high and the exposed population is large should be taken measures first. For the area where noise level is high but rarely population is affected, it can be postponed temporarily to take measures. The platform calculates the number of noise exposed population according to a certain proportion between building noise level and the number of residents. The exposed population of each building can be displayed in different color, and then shown in the city map. Using the map, city manager can easily find the seriously polluted area, and then find the major noise source from the map to take noise reduction measures in time. At the same time, the noise exposed population level also points out the direction of the noise reduction measures. The area where the influenced population is small or the source level is difficult to reduce can take protection measures at the receiver side. The area where noise affects a large population, then the measures to reduce noise source is recommended.

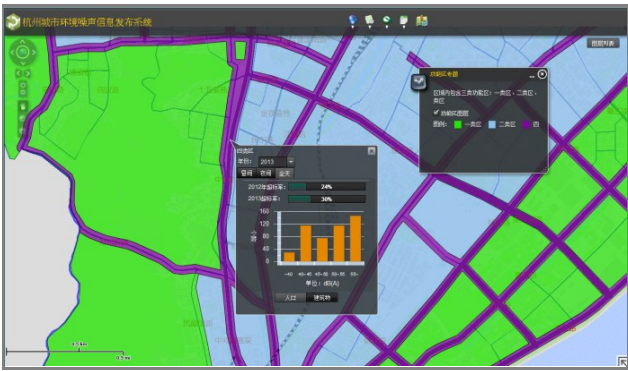


Fig.4 Noise Functional area Graph



Fig.5 Noise and Population Weighted Graph

4.4 Temporary noise control

With the continuous and rapid development of Chinese cities, urban construction has been in a growing trend for a long time. So the construction noise of urban environment has become an important problem. Compared with other noise sources, such as roads, factories and airports, the influence of construction noise is temporary, as the noise will disappear after construction. At the same time, the construction noise sources are complex and changeable due to the change of time and procedures. There is a rule of illegal construction at night, because it has serious interference to people's normal life. With supervising the sound source, the noise pollution problems that affecting residents could be really mitigated and noise environmental quality of the city could be improved [7].

The construction noise control method is built in the noise management platform in Hangzhou. The construction projects in jurisdictions are summarized and noise monitoring is set up during its construction. The noise monitors reflect the real-time noise information to the platform, and it can inform if the noise level is exceed the limit value due to the noise map in time. In this way, the city manager can master the change of the noise of the construction site at any time. Besides real-time warning, the noise impact pattern and influence range of typical construction can also be thoroughly grasped due to the platform, which provide scientific basis for enacting the reasonable standard on construction noise.

4.5 Noise complaint management

The current noise map is a visual display of traffic noise impact to the surrounding environment. In the city life, the noise influence could not be ignored by other types of noise sources. All these noise could give rise to complaints. Hangzhou noise management platform provides a noise complaint module. It offers noise complaint information on the noise display platform, and then summarizes the relationship between noise complaints and noise sources. For higher noise area, noise complaints often appear more frequently. It can often achieve the purpose of reduce complaints through taking the reduction measures to road. But for the regions where the noise level is not high but the complaint is rather frequent, it can't obtain obvious effect if only taking noise reduction measures to roads. In this case, managers should look for the real sound source, improve the regional environment, or try other method, such as landscaping to change people's subjective feeling on the surrounding

environment and reduce the annoyance [8]. Noise complaint management module can fill the shortage of the traffic noise map, and put various noises in the city in the scope of regulation. At the same time, the change of the number of complaints can also be used as an index of assessment of noise pollution control results.

4.6 Updating of noise map

Noise map displays the noise level distribution in the region of the certain period. As known to all, the noise pollution will change as soon as the noise source changes. So shortening the noise map update time has significant importance for city noise management on the premise of considering the cost [9].

The project in Hangzhou integrated the noise automatic monitoring equipment into the platform, while it can get the data collected by the automatic monitoring equipment timely. According to the noise monitoring standard of China, it has road measurement points, regional measurement points and noise functional area measurement points. Combining the fixed measurement stations and mobile measurement to the automatic monitored data, it can predict the changes of road noise source near the measurement point and the change of the city background noise condition. So the updating of the noise map will be achieved. And the noise map updates quarterly now in Hangzhou.

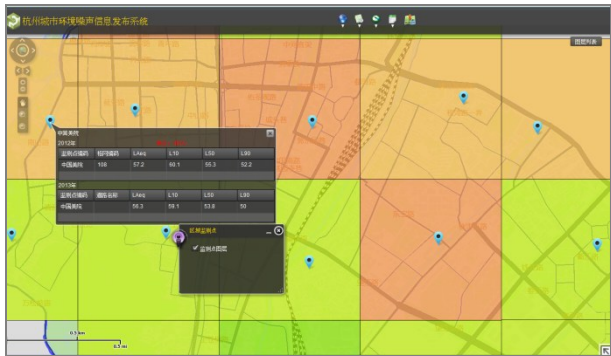


Fig.6 Regional Measurement Data

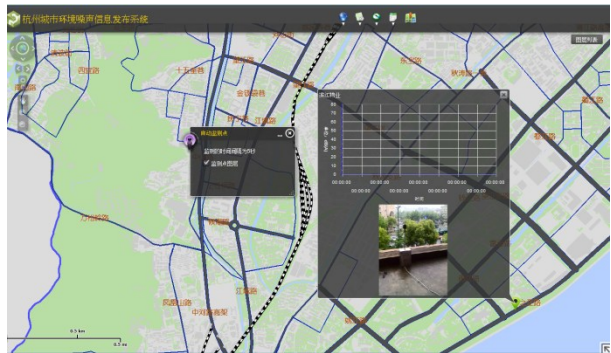


Fig.7 Real-time Monitoring Information

5. Conclusion

The city noise management platform achieves the combination of noise map technology and the actuality city information of Hangzhou city. Because it can calculate, display and analyze noise information, the platform provides great convenience for the Hangzhou noise management authorities. The platform provides scientific basis for formulating reasonable and effective noise control policies. It also makes the application of noise map to be more extensive. The difference map can evaluate the effect of noise mitigation measures. The noise exposure map of noise exposed population can offer the key polluted areas, so it makes the noise control work more targeted. The noise functional area map provides a warning of noise excess with limited levels. Noise complaints platform provides more comprehensive environment noise information. Construction noise regulating and noise map updating dynamically can discover the environment noise problems in time. All above functions can provide a more comfortable sound environment to residents.

The implementation of this project can help to improve scientific and technological level of city noise management in Hangzhou. As it's based on the new-developed "wisdom city" hardware conditions, it provides powerful technical support for noise monitoring and management. It is helpful to propose reasonable development planning, avoiding serious noise pollution problems. At last, it helps to improve the city environmental quality of Hangzhou.

Acknowledgements

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