# Urban Planning Area Traffic Noise Prediction Based on Noise Mapping

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## ABSTRACT

**As the problem of traffic noise pollution got worse, it was a new solution to alleviate traffic noise pollution from the perspective of optimizing road network planning. And noise prediction of planning road network was the basis for optimizing the road network structure. This paper proposed a model to predict the traffic noise of urban planning area and used the model to optimize planning road network. Firstly, it established a traffic noise prediction model based on macroscopic design parameters of roads such as road service level, number of lanes and road grade. Secondly, the model was applied in traffic noise mapping so that the noise mapping was available to calculate the traffic noise pattern of urban planning area. Thirdly, it compared the traffic noise prediction results of six road networks with different road structures. It turned out that noise level was much more related with road density than road structure. The higher the road density was, the higher the noise level was. Fourthly, it came up with two ways to reduce the traffic noise level of the area by decreasing road density and constructing radial road network.**

**Keywords:** planning road network, traffic noise prediction, noise mapping
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## 1. INTRODUCTION

The main cause of traffic noise pollution lay in the structure of the road network. When a road network was built, the traffic pattern was roughly determined. The traffic pattern then determined the potential traffic noise emission level of the road network. If the noise emission pattern could be predicted for a fixed road network structure, it would be possible to optimize the road network planning. The optimization would reduce the traffic noise level in the planning area and lower the impact on people's daily life.

Those existing traffic noise prediction models were almost based on traffic volume and speed because they were aimed at built roads. These models were divided into two categories, including noise emission models and noise propagation models. For noise emission models, Pallas et al.[1] proposed a noise emission model for extending CNOSSOS-EU to light electric vehicles. Lan ZQ et al.[2] proposed noise emission models of light and heavy electric vehicles by data fitting. Peng J et al.[3] proposed a noise emission model for heavy vehicles. And for noise propagation models, Huang BaoXiang et al.[4] modeled traffic noise vertical propagation by neural networks. Wang HB et al.[5] simulated traffic noise propagation in urban built-up area using beam tracing approach. Serraris J[6] simulated noise propagation around different noise barrier models using Scan & Paint 3D. But it didn't work for a planning road network since there was no traffic at all. For this reason, it was necessary to build a model based on road design parameters.

Meanwhile, noise mapping was widely used in traffic noise research. Zhao Weijiang et al.[7] implemented 3D traffic noise mapping with unstructured surface mesh. Taeho Park et al.[8] evaluated the public health impact traffic noise in Gwangju Metropolitan City, Republic of Korea using noise mapping. Wang Haibo et al.[9] computed a 3D noise map of large urban area based on noise mapping and supercomputer. Noise mapping would be a good tool to simulate the noise pattern of a road network.

Firstly, this paper deduced the relationship between road design parameters such as road service level, road grade and number of lanes and traffic flow parameters such as traffic volume and speed. Secondly, it established a noise prediction model with road design parameters as input, which realized the traffic noise prediction of planning road network. Thirdly, it verified the feasibility of the model by a case. Fourthly, it compared the noise emission results of some typical road networks and gave some suggestions on optimizing road network planning.

## 2. MODEL

The traffic noise prediction model consisted of a link model and an intersection model. Here only small vehicles were considered.

The basic form of the link model was the same as the highway traffic noise prediction model. But its parameters were link design parameters instead of traffic flow parameters. The link model was expressed as following[10]:

$$L_{\mathrm{eq}}^{\mathrm{link}} = 12.6 + 33.66 lgV + 10\lg\frac{Q}{TV} + 10\lg(\frac{r_0}{r}) - 16 + 10\lg\left(\frac{\theta}{180}\right) \quad (1)$$

where $L_{\mathrm{eq}}^{\mathrm{link}}$ denoted the noise contribution of a link to a receiver, $Q$ denoted traffic volume of a link, $V$ denoted link speed, $r_0$ denoted reference distance and it was 7.5m in general, $r$ denoted the vertical distance from the receiver to the link, $\theta$ denoted the angle of view subtended by a link at a receiver.

The model above was subject to the following conditions:

link speed:

$$V = V_f(c)\mathrm{P}(k)\mathrm{R}(N) \tag{2}$$

traffic volume of each lane[9]:

$$q = VK_j/e^{2V/V_f(c)} \tag{3}$$

total volume of a link:

$$Q = 2Nq \tag{4}$$

free flow speed[11]:

$$V_\mathrm{f}(c) = -\frac{5}{6}c^3 + \frac{15}{2}c^2 - \frac{95}{3}c + 105 \tag{5}$$

the ratio of speed under a given service level to free flow speed[11]:

$$P(k) = 0.0257k^2 - 0.2983k + 1.178 \tag{6}$$

speed reduction coefficient:

$$R(N) = -0.046N + 1.0453 \tag{7}$$

where $c$ denoted road grade, $k$ denoted road service level, $N$ denoted number of lanes in each direction and $K_j$ denoted the jam density, veh/km/lane.

In this case, an intersection was regarded as a point source. And the intersection was split into two parts which were in different directions, called part 1 and part 2. Then the intersection model was shown below:

$$L_\mathrm{eq}^\mathrm{node} = 10\lg(10^{0.1L_\mathrm{eq1}} + 10^{0.1L_\mathrm{eq2}}) + 20\lg\left(\frac{r_0}{r}\right) \tag{8}$$

where $L_\mathrm{eq}^\mathrm{node}$ denoted the noise contribution of an intersection to a receiver, $L_\mathrm{eq1}$ and $L_\mathrm{eq2}$ denoted the traffic noise emission of part 1 and part 2, $r$ denoted the distance between the receiver and the center of the intersection.

The model above was subject to the following conditions:

traffic noise emission of part 1:

$$L_\mathrm{eq1} = 12.6 + 33.66lgV_1 + 10\lg\frac{Q_1}{TV_1} - 16 \tag{9}$$

traffic noise emission of part 2:

$$L_\mathrm{eq2} = 12.6 + 33.66lgV_2 + 10\lg\frac{Q_2}{TV_2} - 16 \tag{10}$$

speed of each part:

$$V_i = V_{link,i} \cdot E(k) \tag{11}$$

traffic volume of each part:

$$Q_i = Q_{link,i} \tag{12}$$

efficiency coefficient[12]:

$$E(k) = -0.15k + 0.95 \tag{13}$$

where $V_{link,i}$ and $Q_{link,i}$ denoted speed and traffic volume of corresponding upstream link, the efficiency coefficient $E(k)$ represented the ratio of speed in the intersection under service level $k$ to the speed of its upstream link.

## 3. CASE

The road network used for case analysis was selected from the real road network in Guangdong Province, China. The road network was simplified for the convenience of setting parameters and only motorways were left. Its geometric shape was shown as Fig.1 and parts of its parameters were shown in Tab.1 and Tab.2.

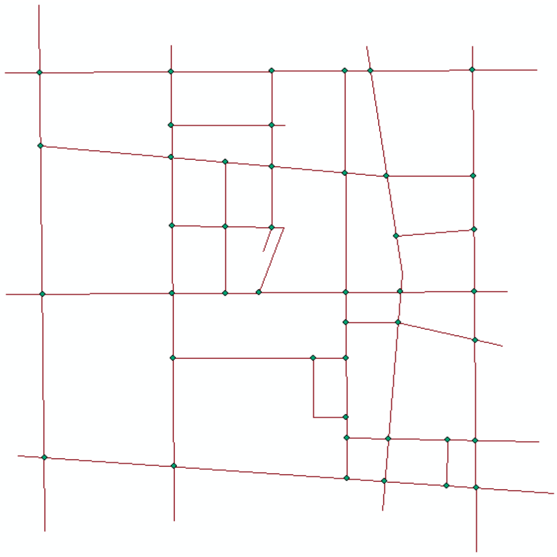


*Fig.1 Geometric shape of the road network*

*Tab.1 Parameters of parts of links*

| Link-ID | Grade | LOS | N |
|---|---|---|---|
| 1 | 1 | 3 | 4 |
| 2 | 1 | 3 | 3 |
| 3 | 1 | 3 | 4 |
| 4 | 3 | 3 | 2 |
| 5 | 2 | 3 | 3 |
| 6 | 1 | 3 | 4 |
| 7 | 3 | 3 | 2 |
| 8 | 3 | 3 | 1 |

*Tab.2 Parameters of parts of intersections*

| Node-ID | Link1-ID | Link2-ID | LOS |
|---|---|---|---|
| 1 | 1 | 2 | 3 |
| 2 | 1 | 5 | 3 |
| 3 | 1 | 17 | 3 |
| 4 | 1 | 8 | 3 |
| 5 | 1 | 23 | 3 |
| 6 | 1 | 6 | 3 |
| 7 | 7 | 2 | 3 |
| 8 | 7 | 5 | 3 |

According to the traffic noise prediction model built in the previous chapter, and with the help of traffic noise mapping, the noise map of the road network was computed and shown as Fig.2.

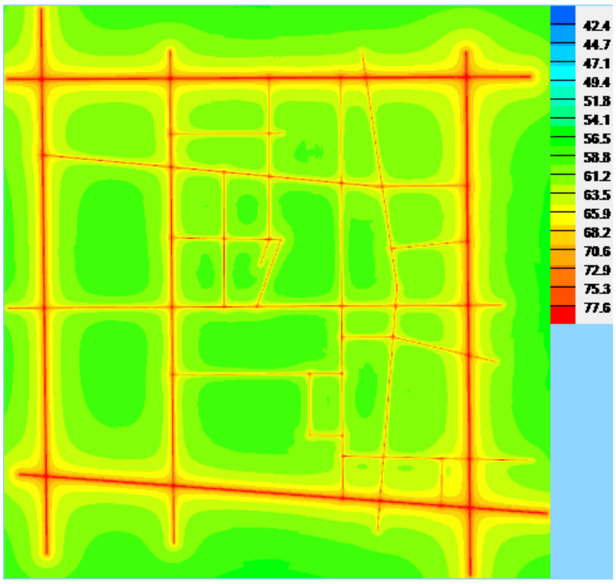
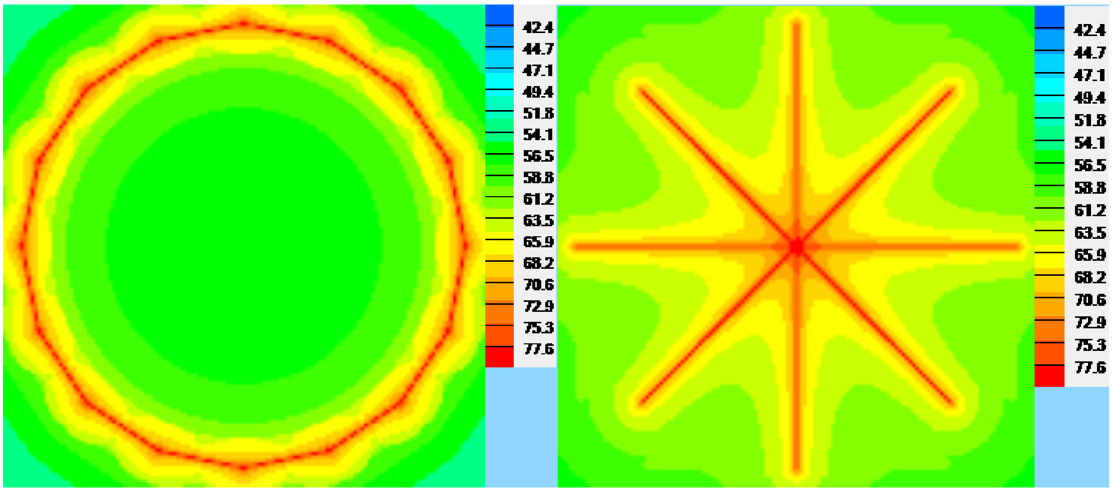



*Fig.2 Noise map of the road network*

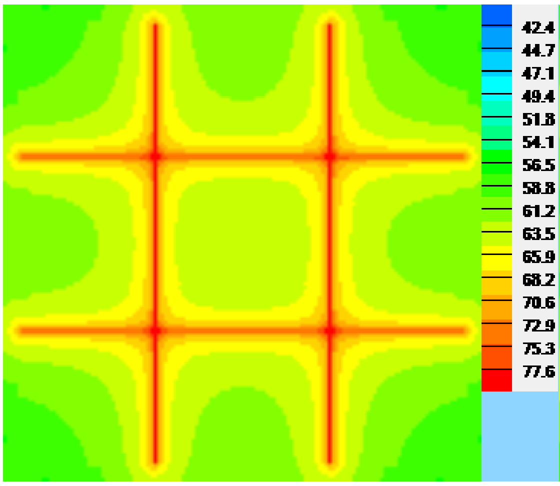
The noise prediction result showed that the minimum value of traffic noise in the area was 56.44dB. And the noise values of nearly 94.88% of the area were no more than 70dB, which meant the ambient noise level in the area roughly reached the goal at day-time.

## 4. COMPARISON

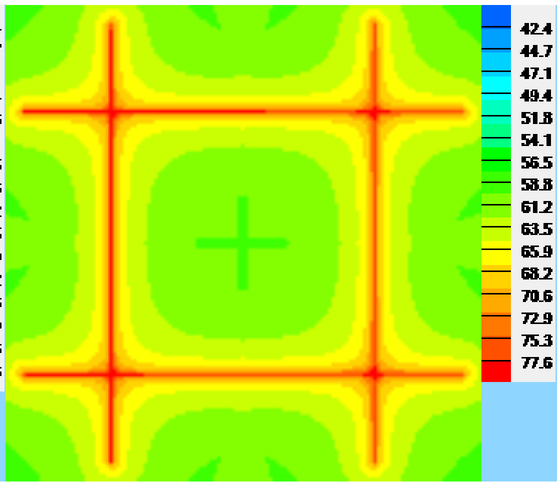
To find out the characteristics of different road networks in traffic noise emission, the traffic noise patterns of three kinds of typical road networks in urban area were compared. The roads in these road networks were set to be 500m in length for lines or 250m in radius for circles. Each road was 2 lanes in each direction with lane width of 3.75m and road grade was level 2. The level of service was level 3 for links and intersections. $K_j$ was set to 80veh/km/lane. The traffic noise patterns were shown as Fig.3a to Fig.3f.



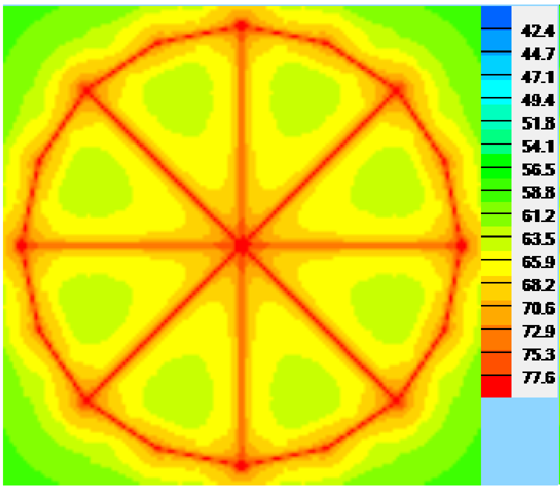

*a. ring* *b. radial*



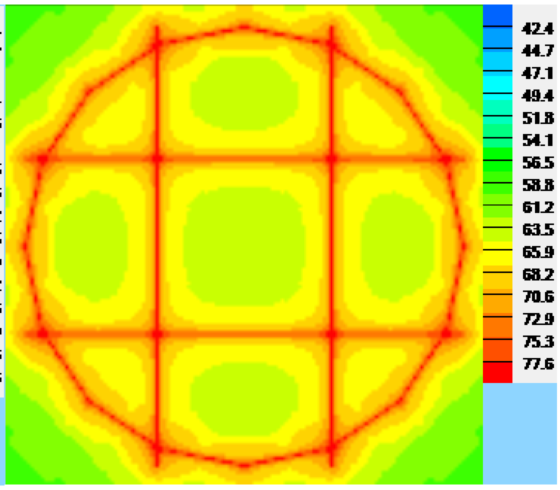

*c. grid-200m*




*d. grid-300m*




*e. ring-radial*




*f. ring-radial-200m*

*Fig.3 Noise maps of different road networks*

In the road networks above, the road density of a was 5.4km/km$^2$, were 6.9km/km$^2$ of b, c and d, and were 12.2km/km$^2$ of e and f. The noise prediction results of each road network were counted in 1dB interval and the count results were normalized. The normalized results and the cumulative curves were shown as Fig.4 and Fig.5.

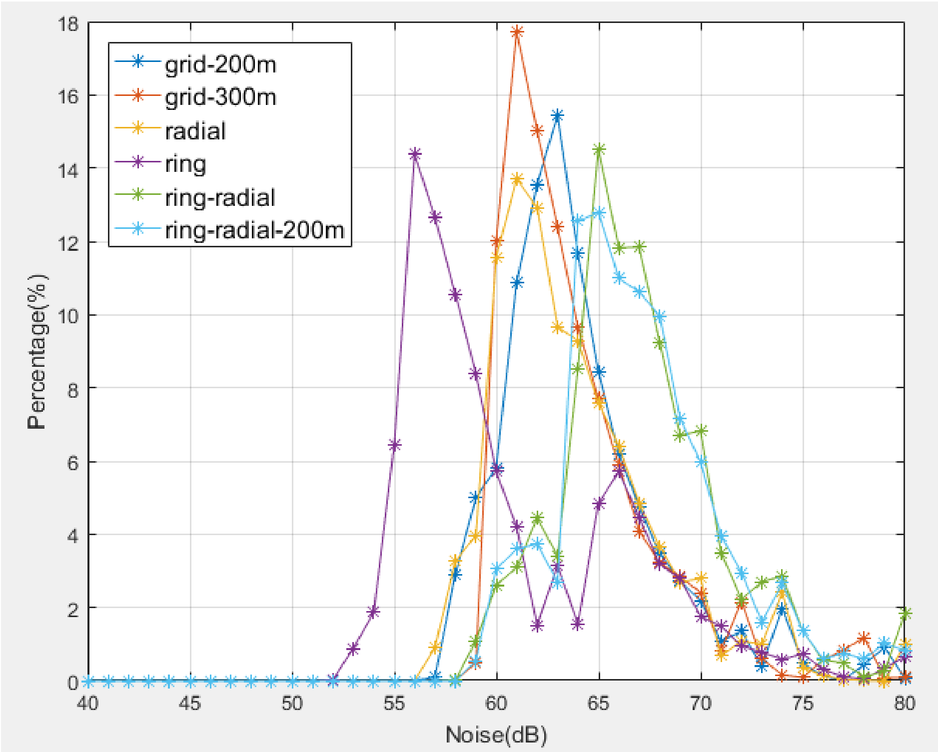



*Fig.4 Normalized count results*

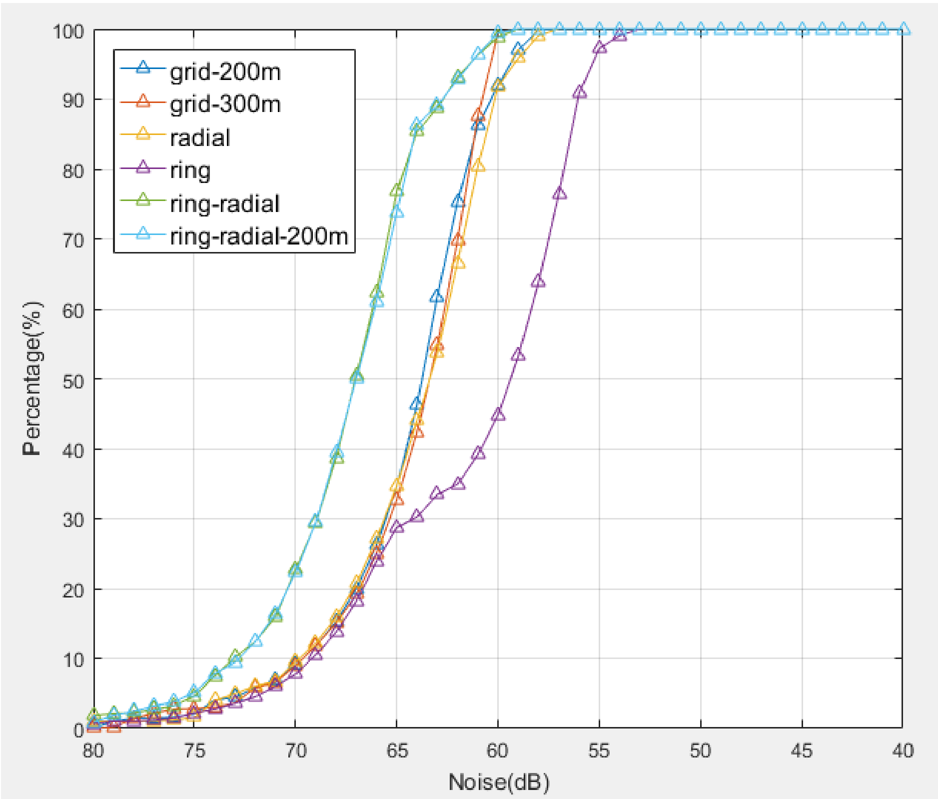



*Fig.5 cumulative curves*

Fig.4 showed that with road density increasing, the noise value where the maximal percentage appeared also increased, from 56dB to 65dB. While Fig.5 showed that with road density increasing, the cumulative percentages during a specific noise interval increased simultaneously. Just as it showed, the six curves could be classified into three kinds, which was consistent with three kinds of road density. The cumulative percentages of road network e and f were larger than that of the others during the interval 61dB to 75dB, and that of b, c and d were larger than that of a during the interval 55dB to 65dB. The weighted average noise values of the six noise maps were 60.90dB, 63.80dB, 64.04dB, 63.95dB, 67.05dB and 67.03dB. In a word, with road density increasing, noise level of the area increased. It was obvious since high road density meant high traffic intensity.

Though the cumulative curves of road network b, c and d were similar with each other, there were some differences. Fig.4 showed that the percentages of road network c and d were larger than that of b during the interval 62dB to 65dB. In fact, the percentages of road network b were larger than that of c and d when noise was up to 80dB. Then it turned to Fig.3. In road network b, roads were more concentrated in the center and more dispersed in the surrounding area. The road geometry determined that sound energy density was higher in the center and lower in the surrounding area. The unbalanced distribution of sound energy resulted in the difference during the interval 62dB to 65dB. In addition, as Fig.4 showed, the percentages of road network c were greater than that of d during the intervals 57dB to 59dB and 63dB to 65dB while during the interval 60dB to 62dB conversely. Fig.3 showed that the roads of road network c were closer to each other than that of d. Thus it was noisier in the central area and quieter in the four corners in the area of c.

The cumulative curves of road network e and f stayed even closer. That was due to high road density. The main difference was in the circle. Fig.3 showed that noise energy was more concentrated in the center of road network e but distributed more balanced in f. The noise patterns outside the circle were nearly the same.

## 5. CONCLUSION

In this paper, a traffic noise prediction model was built to predict traffic noise of urban planning area. The model consisted of a link model and an intersection model. The parameters of the model were road design parameters instead of traffic flow parameters. The model proofed feasible by predicting the traffic noise pattern of a real road network through noise mapping.

Then the traffic noise patterns of six road networks with different road structures were compared. The comparison suggested that noise level was much more related with road density than road structure. The higher the road density was, the higher the noise level was. It indicated that whatever the road network was, it was more effective to lower noise level by decreasing road density.

When road density was the same, the noise level of radial network tended to be lower than that of grid network. While the noise level of concentrated grid network tended to be greater than that of dispersed grid network. It suggested that it was better to construct radial road network than grid road network when considering traffic noise control from a global perspective. But the acoustic environment in the central area was worse.

## 6. ACKNOWLEDGEMENTS

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## 7. REFERENCES

1. Pallas MA, Berengier M, Chatagnon R, Czuka M, Conter M, Muirhead M, *"Towards a model for electric vehicle noise emission in the European prediction method CNOSSOS-EU"*, Applied Acoustics (2016)
2. Lan ZQ, Cai M, Li F, Yang WJ, *"Study of the Traffic Noise Source Emission Model and the Frequency Spectrum Analysis of Electric Vehicles on Urban Roads in china"*, Acta Acustica United with Acustica (2018)
3. Peng J, Parnell J, Kessissoglou N, *"A six-category heavy vehicle noise emission model in free-flowing condition"*, Applied Acoustics (2019)
4. Baoxiang Huang, Zhenkuan Pan, Zunren Liu, Guojia Hou, Huan Yang, *"Acoustic amenity analysis for high-rise building along urban expressway: Modeling traffic noise vertical propagation using neural networks"*, Transportation Research Part D (2017)
5. Wang HB, Cai M, Luo WL, *"Areawide dynamic traffic noise simulation in urban built-up area using beam tracing approach"*, Sustainable Cities and Society (2017)
6. Serraris J, *"Propagation of sound around different noise barrier models using a three-dimensional scan based sound visualization technique"*, Noise Control Engineering Journal (2016)
7. Wei-Jiang Zhao, En-Xiao Liu, Hee Joo Poh, Binfang Wang, Si-Ping Gao, Ching Eng Png, Kelvin Wenhui Li, Shyh Hao Chong, *"3D traffic noise mapping using unstructured surface mesh representation of buildings and roads"*, Applied Acoustics (2017)
8. Taeho Park, Minho Kim, Chaemi Jang, Taeryang Choung, Kyung-A Sim, Dongju Seo, Seo Il Chang, *"The Public Health Impact of Road-Traffic Noise in a Highly-Populated City, Republic of Korea: Annoyance and Sleep Disturbance"*, Sustainability (2018)
9. Wang Haibo, Cai Ming, Yao Yifan, *"Traffic noise mapping in urban area based on supercomputer"*, Technical Acoustics (2017)
10. Yufen Zhang, *"Road traffic environment engineering"*. China Communications Press (2008)
11. Transportation Research Board, *"Highway Capacity Manual 2000"*, China Communications Press (2007)
12. Jingjin Yuan, Zhenzhou Yuan, *"Analysis of Signal Intersection Service Level Evaluation System Indexes and Its Application"*, Technology of Highway and Transport (2006)