Study of Urban traffic ambient noise characteristics based on cluster analysis

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Submission date: July 29th, 2014

Text words including the abstract, text and reference 2627 +5 figures (5×250=1250) =Total 3877.

ABSTRACT

Urban transportation system as the urban arterial has also been rapidly developed in recent years. For example, public transportation passenger capacity had been up to 21.96 million passengers a day by the end of 2013 in Beijing City. Developed city transportation system brings great convenience to travel, however, it should not be ignored that urban traffic noise has been emerging accompanying with that. Moreover, urban traffic noise is becoming more and more severe with the continuous boost of the urbanization process. For those people with poor noise tolerance, such as the elderly, infants and young children, the possibility of suffering noise damage are obviously higher than those normal adults. In order to protect the vulnerable groups' health, traffic noise characteristics produced in all kinds of public transport environment of Beijing are analyzed in this paper based on clustering analysis. All the traffic noise data are separately categorized in the whole frequency region, in the low frequency region(≤200 H_Z) and in the high frequency (≥2KH_Z) .The classification results of various traffic ambient noises in different frequency region are acquired. Traffic noise characteristics between in residential area near overpass road and in residential area near ordinary road are also analyzed based on data collected from specific test location. These results not only can offer theoretic basis for people to understand these noises comprehensively and consciously mitigate noise side effect, but also can offer technical support for government making-decisions.

Key words: Urban traffic ambient noise, Frequency, Cluster analysis, Characteristics

INTRODUCTION

Noise damages to health can generally be classified into two categories: physiological effects and psychological effects. Physiological effects include hearing impairment, sleep disturbance, cardiovascular effects, psychiatric symptoms, fetal development and so on *(1)*. Psychosocial effects include noise annoyance, reduced performance, increased aggressive behavior etc. *(2)*. High Sound level noise and low frequency noise are two severe public hazard and then sound level and frequency are often used to describe all the Physiological effects and psychosocial effects caused by noise. Among them, sound level is more commonly used in various researches. Almost all the noise criteria in the world are formulated by sound level. International Organization for Standardization states a long-term average sound pressure levels (L_{Aeq}) of > 85 dB (A) are likely to cause significant hearing loss*(3)*.A daily average sound exposure equivalent to L_{Aeq} = 70 dB(A) is considered to be safe for the ear *(4)*.Except for standards formulated by sound level, most researches are carried out by it. It has been reported that Schoolchildren' Reading and memory would be impaired when they were exposed to high levels of aircraft noise *(5)*.Children exposed to high levels of community noise had higher stress hormone levels and higher mean blood pressure *(6)*.During sleep, awakening reactions can be detected when event-related maximum noise levels (L_{AF}) exceed some limit value in bedroom *(7)*.

Although so many researches have been conducted based on high sound level, low frequency still cannot be ignored. Low frequency noise (LFN) is refers to the frequency below 200 Hz which can affect our lives in unforeseen ways, from disrupting sleep to making us inexplicable irritable or nervous. Low frequency noise (infrasound included) is the superpower of the frequency range, which is attenuated less by walls, buildings and other structures, can rattle walls and objects, masks higher frequencies, crosses great distances with little energy loss. LFN is also able to produce resonance in the human body and causes great subjective reactions. Its hazards are more severe than mid- and high frequencies'. These features confirm that the effects of LFN noise is deserved to further study. Dramatic examples are shown as below: In 1974, Liszka found Noise at 2 Hz apparently emanating from oil rigs in the North Sea also has been detected in Sweden *(8)*.In 1978, Liszka also found the sonic booms of supersonic aircraft flying between Europe and New York could produce low-frequency noise levels as strong as 75 dB as far away as the North of Sweden *(9)*. It was recorded that low-frequency sound waves travelled around the earth several times after the volcanic eruption of Mt. Krakatau, and a sound wave of 0.1 Hz will loose only 5% of its energy in traveling around the earth *(10)*. Late research have found that LFN can result in significantly decreased subjectively judged working capacity, such pronounced deterioration of highly demanding task performance as proof-reading task and verbal grammatical reasoning task *(11, 12)*. Complaints following exposure to LFN include: fatigue, feeling of apathy, loss of concentration, somnolence and depression *(13)*.

Urban roads and traffic in China are rapidly increasing. A comprehensive road traffic network is forming, in which all kinds of vehicles, i.e. cars, trucks, bus, light rail trains, subways, now are running day and night in the modern city. In Beijing, for example, there were 21.148 million permanent population, 5.437 million vehicle ownership, 22,486 public operating electrical vehicles, and 4.9 billion yearly passenger volumes by the end of 2013. The rail transit operation length is up to 465 km, with 3.21 billion yearly passenger volumes. Rapid development of traffic has brought great convenience for residents, but at the same time, road traffic noise pollution is also becoming a great public hazard to China's urban environment. Traffic noise, with shifty sound sources, high sound level, long time interference, seriously disturbs normal life of urban and rural residents. Especially in recent years, urban construction and expansion of streets and roads make remote and quiet areas into bustling and noisy city.

More and more tall buildings standing on both sides of the road make noise bouncing back and forth in the street canyon, which further aggravates the impact of traffic noise on the surrounding environment. In large and medium cities of our country, more and more city residents living in excess noise environment, the traffic noise pollution complaints continue to rise. Noise sources associated with modern urban transportation system can include passenger vehicles, medium trucks, heavy trucks, buses and subways etc. Each of these vehicles produces noise, however, the source and magnitude of the noise can vary greatly depending on vehicle type. Simultaneously, the construction patterns of infrastructure and road grade also determine the difference of the noise. In this study, traffic environment noise data of Beijing city is collected and analyzed by Cluster Analysis. The results not only can provide a theoretical basis to protect public health, but also provide technical support for noise engineering control measures.

CLUSTER ANALYSIS

Cluster analysis is a statistics method which can be used to categorize object based on corresponding data. The common characteristics of this method is that the number of categories and structure are unknown in advance and similarity or dissimilarity between objects or data is the basis of analysis. The similarity or dissimilarity is considered as a metric of the "distance" between objects. Objects with a smaller “distance” are collected into one category and objects with a bigger “distance” can't be collected into one category. Hierarchical clustering method is one of the most widely used clustering analysis methods. Its mechanism follows below: first, supposing n samples as n categories and stipulating the distance among samples and the distance among categories; and then merging the nearest two samples into a new category and calculating the distance between the new categories and other categories; Repeating merging the nearest two categories according to the above procedure and reducing a new category each time until all the samples are merged into one category *(14)*.

Hierarchical clustering method include many specific methods, e.g., the smallest distance method, the biggest distance method, middle distance method, class average distance method, the center-of-gravity method and Ward's method. In this study, the smallest distance method is adopted to categorize the objects in which the smallest “distance” of each 2 samples is presumed as the “distance” of all samples.

Equation 1 represents sample G_K and sample G_J merging G_M.

$$D_{KL} = \min d_{ij} \quad (i \quad G_{K,} \; j \quad G_L) \tag{1}$$

Then, computing the distance between G_M and G_J, the Recursion Formula is shown as below:

$$D_{MJ} = \min d_{ij} \quad (i \quad G_{M,} \; j \quad G_J) = \min\left\{\min d_{ij} \; \left(i \quad G_{K,} \; j \quad G_J\right), \min d_{ij} \quad (i \quad G_{L,} \; j \quad G_J)\right\}$$
$$= \min\left\{D_{KL}, D_{LJ}\right\} \tag{2}$$

CHARACTERISTICS ANALYSIS OF URBAN TRAFFIC AMBIENT NOISE

1 Characteristics Analysis of Urban Traffic Ambient Noise Based on the Smallest Distance Method

In order to analyze the noise characteristics of different traffic environment, test locations of typical traffic noise in Beijing city have been carefully chosen. Measurement time of data collection is set as about half an hour for each test location. Noise collecting sites include: beside the track of subway, outside station of subway, inside platform of subway, inside subway train, inside express rail train, inside bus, inside car (80Km), near overpass bridge, near branch way.

The characteristics of all the noise data measured in each test location are shown as Fig.1. It is clear that sound level of LFN is much higher inside bus, inside car, inside subway train, inside express rail train and sound level of LFN is much lower inside platform of subway, outside station of subway. It is very hard to distinguish all the differences among all the noise data only by observing the noise plot in the whole frequency region displayed in Fig.1. It is well known that traffic noises belong to low frequency noise, higher sound level mainly focus on low frequency region which is always less than 500H_Z. In order to clearly analyzed noise characteristics, all the noise data are separately categorized at a whole frequency region, at a frequency region which is less than 200 H_Z and at a frequency region which is more than 2KH_Z .

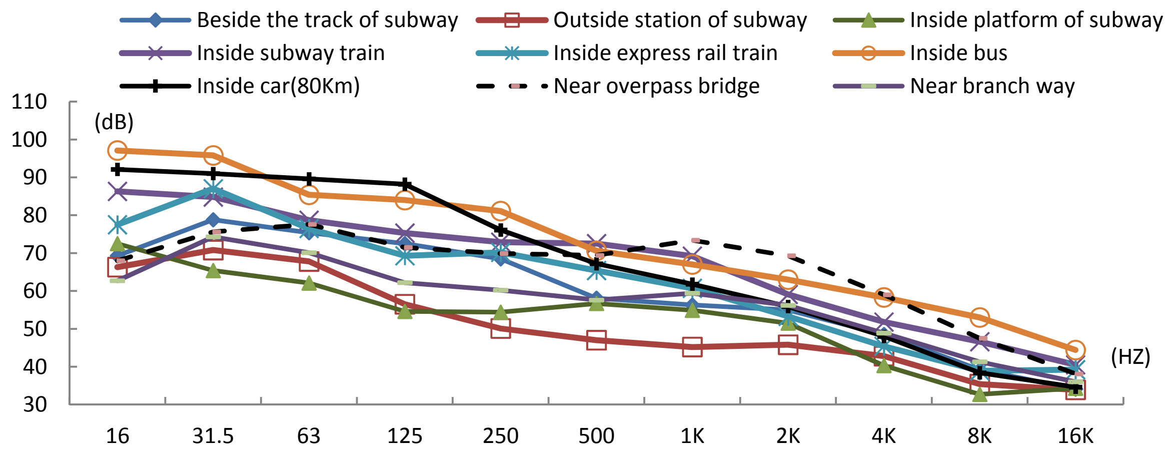

Figure 1 Characteristics of all kinds of urban traffic ambient noise

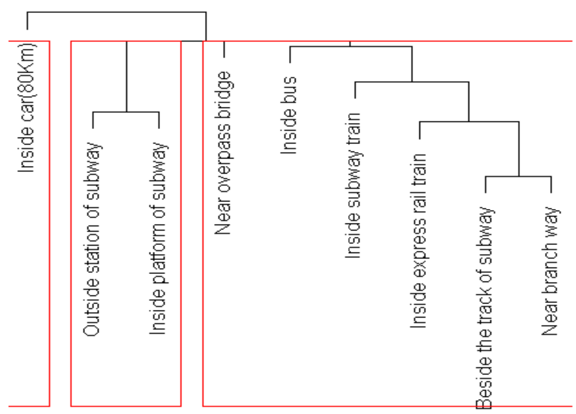

Figure 2 Categorizing traffic ambient noise in whole frequency region
by the smallest distance method

Fig.2 shows that in whole frequency region, noise from near overpass bridge, inside bus, inside subway train, inside express rail train, beside the track of subway and near branch way are merged into one category, noise from outside station of subway and inside platform of subway are merged into another category and noise from inside car (80K m) forms one category by itself. Fig.3 shows that in frequency region (⩽200 H_Z), noise from inside bus and inside car (80K m) are merged into one category, noise from near branch way, near overpass bridge, beside the track of subway, inside subway train and inside express rail train are merged into one category, noise from outside station of subway and inside platform of subway are merged into one category. Fig.4 shows that in frequency region (⩾2KH_Z), noise from inside express rail train, beside the track of subway, inside car (80K m), near branch way, outside station of subway and inside platform of subway are merged into one category, noise from inside subway train and inside bus are merged into one category, noise from near overpass bridge is sui generis.

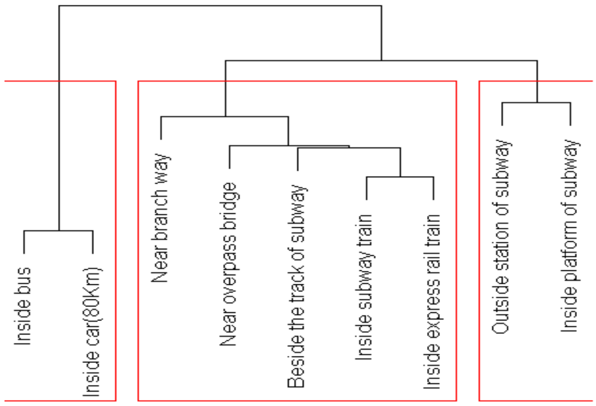

Figure 3 Categorizing traffic ambient noise in frequency region(≤200 H_Z)
by the smallest distance method

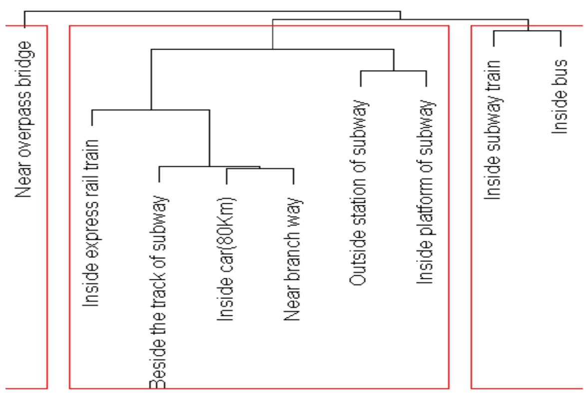

Figure 4 Categorizing traffic ambient noise in frequency region(≥2KH_Z)
by the smallest distance method

2、Analysis of Indoors Traffic Noise Characteristics nearby Overpass Bridge and nearby Branch Way

In order to compare noise impact on residential area, indoors traffic noise nearby Overpass Bridge and indoors noise nearby branch way are both measured very near from room window. Residential buildings nearby Overpass Bridge are equipped with double glazing. Test states are respectively set to 3 cases: opening window, closing one layer window and closing two layers window. In order to abating road traffic noise, residential buildings nearby branch way are equipped with glass curtain wall outside exterior wall which are facing street. There are some small ventilation windows on glass curtain wall. Windows of this building has only one layer glass. Test states are also set to 3 cases: opening window (open small window on glass curtain wall and room window), closing one layer window (close small window on glass curtain wall and open room window) and closing two layers window (close both room window and small window on glass curtain wall). Test results are shown as Fig.5. The overall level of noise sound level nearby overpass is higher than that nearby branch way, especially when opening windows. When close one layer window, indoors noise nearby overpass can be abated 10~20dB in whole frequency region. When closing double window, low frequency noise(≤63Hz) almost can't be shielded any more. It can be inferred that low frequency structure noise emerges indoors. In high frequency part, the filter capacity of the second layer glass is clearly smaller than the first layer glass. It also can be inferred that high frequency structure noise also emerges indoors, but the increment of high frequency structure noise is smaller than that of low frequency structure noise. Noise nearby branch way can hardly be filtered when closing small window on the glass curtain wall. Due to many air conditioning machines hanging on the exterior walls, and then there are many small window on Glass curtain wall which are always open for ventilation. These small open windows make it very difficult to prevent low frequency noise less than 200 Hz. Part of high frequency noise can be abated by glass curtain wall. When closing double window ,i.e., closing both room window and small window on glass curtain wall, indoors noise nearby overpass can be abated 10 dB ~15dB in whole frequency region.

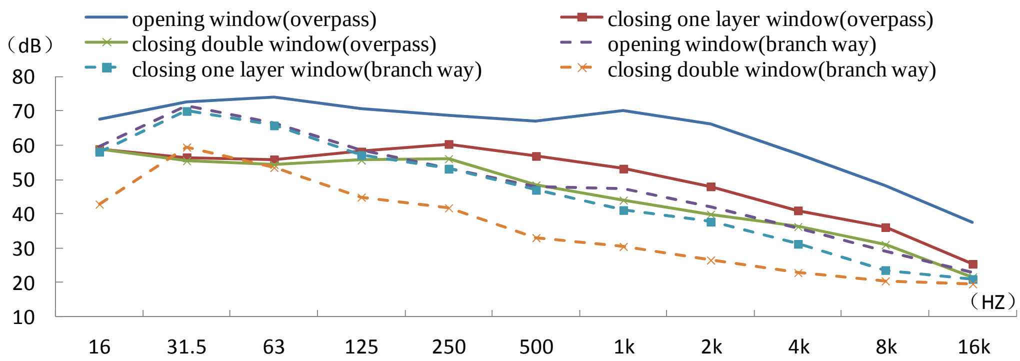

Figure 5 Indoors noise characteristic between nearby overpass bridge and nearby branch way

CONCLUSIONS

Classic traffic ambient noise data of Beijing city are measured and analyzed in this study, which offer a comprehensive recognization to the characteristic of these specific noises, especially for those hazard factors such as high sound level noise part and low frequency noise part. In order to categorize all the traffic ambient noise in Beijing city, the smallest distance method, one of cluster analysis method is adopted in this study. The results separately shows the similarity between noises at 3 kinds of categories conditions: in whole frequency region, in frequency region(≤200 H_Z) and in frequency region(≥2KH_Z). The results of this research makes a better understanding of these specific noise and is helpful for people to know these noises clearly and consciously mitigate risk caused by noise. Of course, it also offers some theoretic support for formulating new noise abatement measures.

For rooms nearby urban roads, no matter it is near Overpass Bridge, express way or branch way, indoors traffic noise can't be effectively mitigated by glasses equipped on windows because traffic operation has caused structure vibration noise.

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