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# Railway environmental noise control in China

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**Abstract**

Railway transportation has made significant contributions to the flourishing economy of China, the environment-friendly development of the system having become one of the major challenges. Noise pollution in particular has been the subject of much attention in recent years. The present situation in China regarding railway environmental noise is given in this paper. Emission standards and methods of measurement of railway noise on the boundary alongside the railway line (GB12525-90) is first introduced, followed by typical noise levels and spectra alongside main railway lines and the noise propagation pattern with distance (which have been monitored over decades). The primary sources of railway noise to residential communities include the whistling noise of locomotives, the noise of diesel locomotives and wheel/rail noise. According to the characteristics of these noise sources and their impacts, various effective noise control technologies have been adopted. Environmental Impact Assessment (EIA) has been well implemented for all new railway projects to ensure that the noise impact is given early consideration. However, increasing the speed on existing lines, constructing new high-speed passenger lines and developments of heavy freight transport are among the main improvement works of Chinese railways in the near future. Finally, there is a brief perspective of the key research objectives in the field of railway environmental noise.


## 1. Introduction

China is a country of enormous territory and huge population, with unevenly distributed resources. The imbalance in the economies between various areas in China saddles its railway with the burden of transporting large amounts of freight and long distance passengers. Of the various transport options nowadays in China, railway transport plays a key role. The system comprises around 70,000 km. The highest speed of passenger trains on trunk lines is 160 km/h. Thus the day-to-day environmental impact of railway noise is acute.

## 2. The present situations of the railway noise impacts and railway noise control in China

### 2.1. Situation of railway operation noise pollution

The Chinese railway network is mainly in the eastern part of China. The main trunk lines, such as Beijing–Shanghai, Beijing–Guangzhou, Xian–Shanghai, Shanghai–Zhuzhou, are located in Northeast,

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Southeast and Northern Coastal China. Railway noise impact varies from region to region. According to a survey of the noise impact alongside railway lines among the major cities in China, the noise pollution is much higher than other Chinese cities. In these metropolitan cities, the average day–night noise level $L_{A\mathrm{eq}}$ at 30 m from the centreline of the outer track has already reached 70 dB, while in the western part of China, in the capital cities Kunming, Chengdou and Wurumuqi, the sound level at the same reference point is lower than 70 dB [1]. The average day–night noise level $L_{A\mathrm{eq}}$ mentioned above is defined as

$$L_{\mathrm{eq}} = 10\log\left[\frac{16}{24}10^{L_{\mathrm{day}}/10} + \frac{8}{24}10^{L_{\mathrm{night}}/10}\right]\,\mathrm{dB(A)}, \tag{1}$$

where 16 h is the duration of 'daytime', and 8 h for night. There is no weighting for the night period in this formula.

According to the technical criteria employed in China, railway lines fall into three classes: trunk line, branch line and specific railway line. The noise pollution alongside the railway varies according to the lines. The noise level at the boundary of the higher speed area of the main railway trunk lines of China nowadays is $L_{A\mathrm{eq}} = 69.8-74.3$ dB in daytime and 69.3–74.8 dB at night. This has already exceeded the standard GB12525-90 (see Section 3 below), being around 0–5 dB above the limit of 70 dB. However, according to practical measurements, the limit might be met at 45 m away from the centreline of the outer track [2]. The noise level of branch lines is $L_{A\mathrm{eq}} = 61.5-70.6$ dB in daytime and $L_{A\mathrm{eq}} = 59.1-67.4$ dB at night [3], which shows that they are capable of meeting the limits required by the standard GB12525-90.

In recent years, the speed of Chinese trains has increased and both the loading of wagons and the intensity of the flow of trains have grown, leading to serious noise pollution along the line of the railway. The $L_{A\mathrm{eq}}$ along it has climbed by 2–3 dB. Following the promulgation of the "Law of Preventing and Eliminating Environmental Noise Pollution of People's Republic of China", and other relevant regulations, the railway authority and governments at each level adopted a lot of active and effective measures to control railway noise pollution. In some places and to some extent, noise levels at the railway boundary is under control. For instance, in the urban area of Beijing the use of locomotive whistles is restricted by municipal regulations; the direct effect of this restriction has been a decrease in the noise to under 70 dB at the boundary in many areas [4]. However, from a nationwide point of view, the task of noise control needs strong enhancement to meet even the minimum requirements demanded by the standard GB12525-90.

### 2.2. Composition of main sources of noise

The environmental noise of the Chinese railway is generated mainly from two groups of sources, i.e. railway line noises and railway station noises. Railway line noise includes the whistling noise of locomotives and train operating noises (composed of rolling noise, traction noise and aerodynamic noise). Railway station noise includes the whistling noise of locomotives in passenger stations, freight stations, operating stations, engineering workshop and train workshop as well as loudspeaker broadcasts in these various places [5].

The locomotive whistle is a noise source characteristic of China. It is attributable to the "Railway Technique Operation Management" laid down by the Railway Ministry of China. This stipulates that the locomotive whistle is to be used for necessary of communication and warning. In developed countries, locomotives are connected with each other by wireless communication equipment and, besides, the replacement of level crossings with flyovers reduces the necessity to use a whistle. In many areas of China, however, the diesel locomotive still uses its whistle as the signal of communication and warning. The noise source of the whistle is located at the top of the locomotive, 4.5 m above the track surface. The largest sound power in the noise frequency spectrum is concentrated within the range 5000–8000 Hz. The $A$-weighted sound pressure level of the whistle at a distance of 30 m to the trackside is between 98 and 110 dB [6]. According to a survey of main trunk lines, such as Beijing–Shanghai, Beijing–Guangzhou, Harbin–Dalian, Zhejiang–Jiangxi, and Lung–Hai, noise measurements at the railway boundary show that whistle noise can occupy 70% of the total energy in $A$-weighted equivalent continuous sound pressure level at some particular sites near railway stations, alongside some railway line sections in urban regions [7]. This demonstrates that among the existing railway noise sources, whistle noise is the most important in China.

Train operating noise depends closely on both the speed of the train and the train flow capacity. In China, train operating noise is dominated by wheel/rail noise.

According to measurements in China [8], when the speed of the train $v$ is above 100 km/h, the equation for wheel/rail noise is

$$L_p(v) = L_p(v_0) + 20\lg\left(\frac{v}{v_0}\right) \tag{2}$$

and when $100 < v < 300$ km/h, the equation for wheel/rail noise is

$$L_p(v) = L_p(v_0) + 30\lg\left(\frac{v}{v_0}\right), \tag{3}$$

where lg means $\log_{10}$ and $v$ is train speed. $L_p(v)$ means maximum $A$-weighted sound pressure level during a pass-by. That is to say, doubling the train speed increases the operating noise level by 6–9 dB. In China, train speeds have increased greatly since 1997, and the $A$-weighted equivalent continuous sound pressure level at the boundary of railway trunk lines has increased accordingly, by up to 2–3 dB if the horn noise source is not considered.

At railway stations or railway workshops, there is usually loudspeaker equipment installed for the purpose of communication and operational control. The constant use of this equipment, characteristic of these sites, means they become a noise source seriously detrimental to the neighbouring environment. The $A$-weighted sound level at 50 m away from the column-type loudspeaker installed at a high place reaches 80–85 dB, with much high frequency sound usually. The largest sound power is concentrated within the range 1000–4000 Hz.

### 2.3. The extent of railway environmental noise impact

For Chinese passenger train operating noise, on regular speed railways, the maximum sound level of a passing train varies with distance in free field according to Ref. [8]

$$\text{when } d \leqslant 150\,\text{m} \quad \text{then } L_d = L_{d_0} - 10\lg\left(\frac{d}{d_0}\right), \tag{4}$$

$$\text{when } d > 150\,\text{m} \quad \text{then } L_d = L_{d_0} - 20\lg\left(\frac{d}{d_0}\right). \tag{5}$$

This means that when the distance from the train is doubled, the maximum sound level of the passing train reduces by 3–6 dB.

According to the statistics of practical measurements, due to the existence of various buildings along the railway, at 45 m away from the centreline of the outer track, the noise impact ($L_{A\text{eq}}$) may be lower than 70 dB by day/night, i.e. within the requirements of the standard GB12525-90. At a distance of 100 m, the railway noise impact may be below 60 dB [2].

### 2.4. The present situation of railway noise control

In China, the initial research into railway noise began in the 1960s, focusing mainly then on the impact of railway noise on the human body. In the 1970s, the noise and vibration control of the then current diesel locomotive engine was studied. In the 1980s, researchers turned to the drafting of Railway Boundary Noise and Railway Environment Vibration Criteria and the Railway Environmental Impact Assessment (EIA) was introduced in that period. In the 1990s, speeded by the need for railway construction environmental assessment, areas such as the mechanism of railway noise emission, the pattern of railway noise prediction, the characteristics of locomotive whistling noise, methods of control of noise of regular speed railways, etc. were all targeted. In recent years the characteristics of the noise and vibration source in express railways and the drafting of standards concerned with this have been studied.

### 2.4.1. Locomotive whistling noise control

With regard to the control of locomotive whistle noise, the Chinese railway authority are pursuing the following studies: restriction of the use of whistle in metropolitan urban areas, drafting a prescribed standard for the acoustic property of locomotive whistles, the adoption of a new type of whistle, noise proof and with strong directional properties, etc.

Because the most important source of railway noise in China is the locomotive whistle, in 2001 the State Environment Protection Bureau and the Railway Ministry of China promulgated jointly a notification document on "Strengthening the Prevention and Protection Work of Railway Noise Pollution". The railway authorities in Chinese metropolitan cities, such as Beijing, Shanghai, Guangzhou, imposed severe restrictions on the use of locomotive whistles in urban areas. Since then, the $L_{A\text{eq}}$ along the railway boundary (30 m away from the centreline of the outer track) have been reduced by 3–5 dB at the locations where the whistle noise is important. Now the railway authority is summarizing the experience of these cities with the object of popularizing the restriction of whistling in urban areas nationwide.

Again, in order to restrict the environmental impact of whistle noise, as well as to guarantee the necessity of security warning, the Railway Ministry of China has laid down a specific "Technical Specification and Measurement of Acoustical Performance for Locomotive Whistle "TB/T3051-2002. This provides that the sound generated by a locomotive whistle may be composed of several frequencies, but must remain harmonious. For the sake of safety, the $A$-weighted sound pressure level 30 m away on the axis of the whistle, should be at least 107 dB, but for the sake of noise reduction, the sound pressure level 30 m away at an angle $45^\circ$ to the axis should be no more than 98 dB. In other words, the whistle has to have a harmonious tone and strong directional quality.

At the same time, the Chinese railway authority is developing a new whistle with both harmonious tone and strong directional qualities. The form of the new product has now been fixed but it has yet to be manufactured.

### 2.4.2. Broadcast loudspeaker noise control

Nowadays in railway stations and workshops in the metropolitan cities of China, loudspeakers have been replaced by wireless communication and the noise levels of these installations at the boundary has decreased by 1–3 dB. Most of them now meet the requirements laid down by the standard GB12525-90.

### 2.4.3. Train noise control

Various control methods have been adopted comprehensively to lower operational noise, such as streamlining locomotives, low-noise bogies, train skirt, disc braking, reduction in the number of pantographs. The $A$-weighted sound level of a passing train has been decreased by 4–10 dB by these measures.

### 2.4.4. Rail noise control

The main trunk lines in China have been built of heavy steel long-welded rail with elastic fastenings, which has lowered railway noise at the boundary by 1–3 dB. Furthermore, the railway authority concerned is developing a damped steel rail, the experimental stages in the laboratory having been already successfully achieved; the practical application is now going to be examined.

Another method of noise control is the use of ballast in the base of the rail. Rail ballast performs well in vibration absorption. According to site measurement, a railway bridge using ballast in the base of the rail is capable of lowering the noise at the railway boundary by 1–3 dB. Again, the China Academy of Railway Sciences has developed elastic vibration absorptive block for use with non-ballast track, showing that the reduction of vibration and noise can be achieved to some extent.

### 2.4.5. Transmission path control

To control the sound transmission, building sound barriers is the first method adopted. In the mid-1990s, sound barriers were built for the first time alongside railway lines, mainly on the Guangzhou–Shengzheng express line and some parts of Beijing–Zhengzhou railway. It was at that time merely an experimental project for the purpose of sound shield design and to evaluate materials to be used in the barriers. In recent years, barriers have been built on a much larger scale along trunk lines such as: the Jing–Kung, Jing–Qing, Qing–Sheng and Bao–Lan Railways. Up till now, nearly 100 km of sound barriers have been constructed. Two types of sound barrier are used, vertical and folded. Generally, the height of the barrier is around 2–5 m. Sound absorptive material is adopted in their construction. The noise decreasing effect within the sound shadow zone is approximately 3–10 dB. It is predicted that there will be massive development in sound barrier construction in the coming years.

Forestation zone construction is the second method adopted. Forestation along the sides of the railway will not only promote the ecological environment for the city, but also can be able to absorb the noise of locomotive operation. Generally speaking, a forestation zone 10–15 m wide is capable of reducing the noise level by 1–2 dB at the railway boundary. According to the Railway Ministry ordinance, in future years, afforested zone construction will gradually be carried out nationwide, and it is expected that 30,000 km of forested belt will be established.

#### *2.4.6. Control at sound receiver location*

If, when methods of noise source control and transmission path control have been completed, the sound level at sound receiver site still exceeds the relevant criteria, or when the receiver site protection method is, after comparison, better than that of other noise control methods, the sound receiver site protection programme will be introduced. For some sensitive buildings adjoining the railway, such as hospital, schools, residential communities, sound receiver site control methods are usually adopted. The main methods are adjustment of the arrangement of buildings, the installation of sound-proof windows and other such measures to meet their environmental acoustic demands.

## 3. Criteria and management of Chinese railway noise control

### *3.1. Railway environment noise criteria*

There are three criteria governing railway environmental noise. The first one: GB12525-90 "Emission Standards and Measurement Methods of Railway Noise on Railway Line Boundary" is the most common criterion for railway environmental noise limitation at state level. According to this criterion, the boundary is taken to run 30 m away from the centreline of the outer track. The day/night equivalent $A$-weighted sound pressure level at this boundary shall be no more than 70 dB. The Environment Protection Bureau of China is going to revise GB3096-2004 "Environmental Quality Standards & Noise Measurement Method", and in this drafted criterion, the zone alongside railway trunk lines will be treated as same as the zone alongside road transportation highways. This imposes limits of equivalent sound pressure level of 70 dB by day, and 65 dB at night.

The second criterion is TB/T3050-2002 "Specifications for the Measuring Technique of Environmental Noise along Railway Lines" [10] which mainly improves methods of railway noise measurement under different operational conditions and also clarifies the definition of "railway boundary".

The third criterion is TB/T3051-2002 "Acoustic Quality of Locomotive Whistle and its Measurement" [11] which is aimed at the locomotive whistle as the main source of railway noise. It restricts the sound pressure level at a distance of 30 m at an angle of 45° to the axis of the whistle to 98 dB and at the same time regulates the frequency content of the whistle (see Section 2.4.1).

### *3.2. The management of railway environment protection*

#### *3.2.1. Administration of management system*

Responsibility for the protection of the railway environment is vested to the Environment Protection Office of the Railway Ministry, which is authorized to manage and supervise the overall task of railway environment protection. Railway environment protection offices at each level are under the supervision both by the superior railway environment protection office and the local environment protection authority.

#### *3.2.2. Railway construction project environment protection system*

Relevant laws in China require that environmental protection engineering should be carried out simultaneously with the design, construction and putting into production of the main project. In Chinese it is called the "Three Same Time System".

### 3.2.3. EIA of railway construction project

The environmental assessment of railway construction projects is an important part of their administrative procedure, having become an irreplaceable link in the procedural chain. It began in 1987 and has been implemented since then. In all, more than 200 new railway construction projects, or repair and expansion of existing lines were environmentally assessed with the aim of discovering and solving environmental problems before work began. At the initial stage of the railway construction project, its environmental aspects are examined to assess possibilities of environmental impact arising from it. To regulate this work, the Railway Ministry issued in 1993 "Technical Standard of Environment Impact Assessment on Railway Construction Project" (TB10502-93). It regulates the technical methods of environmental impact (including noise) assessment on railway construction projects. In 1995, the Railway Ministry issued "The Management of the Environment Impact Assessment of Railway Construction Project", which regulates the management responsibility, task entrustment, EIA, and handling of disputes, etc. In 2003, the State promulgated the "Law of Environment Impact Assessment of People's Republic of China", which lays down the acute need to evaluate the environment impact of every construction programme and also the relevant legal responsibility for this. This law will undoubtedly benefit the strategy of continuous development in China, prevent the possible negative influences of some construction projects and promote harmonious economic, social and environmental development.

The environmental noise impact assessment of railway construction projects mainly includes an assessment of the existing situation, a predictive assessment and an examination of the feasibility of prevention and treatment methods. The existing situation assessment is to evaluate the noise environment situation at the planned project, through on-site investigation and measurement to ascertain the distribution of sound-sensitive targets along the route of the project, its nature and its spatial relationship with railway, and public demands or comments on the construction at key segments of the project. Visits are made to local environmental and planning authorities and investigations are made of the district development programme along the project route. Assessment of existing situation can only be made on the basis of the detailed and reliable information mentioned above. Predictive assessment is now based mainly on theoretical models to assess railway noise and its possible negative impact.

The formula for calculating predicted equivalent sound pressure level $L_{\mathrm{eq},T}$ caused by railway train operation can be given as follows [9]:

$$L_{\mathrm{eq},T} = 10\lg\left[\frac{1}{T}\sum_{i=1} n_i t_{\mathrm{eq},i} 10^{0.1(L_{p0,i}+C_i)}\right], \tag{6}$$

where $T$ is the evaluation time for day or night, $n_i$ are the numbers of passing trains (category $i$) within the evaluation time, $t_{\mathrm{eq},i}$ the equivalent time of passing trains (category $i$), $L_{p0,i}$ the noise level radiated by train (category $i$), $C_i$ the correction term for the noise of train (category $i$), which can be calculated as follows:

$$C_i = C_{v,i} + C_{t,i} + C_{d,i} + C_{a,i} + C_{g,i} + C_{b,i} + C_{\theta,i} + C_{w,I}. \tag{7}$$

In this formula, $C_{v,i}$ is the speed modification, can be calculated from experimental data, relevant data or criteria; $C_{t,i}$ the railway line structural modification, can be calculated from experimental data, relevant data or criteria; $C_{d,i}$ the geometric attenuation, can be calculated from theoretical formula; $C_{a,i}$ the air sound absorption, can be calculated from relevant formula in GB/T 17247.1; $C_{g,i}$ the ground surface sound absorption, can be calculated from relevant formula in GB/T 17247.2; $C_{b,i}$ the barrier insertion loss, can be calculated from relevant formula in GB/T 17247.2; $C_{\theta,i}$ the vertical directive modification, can be calculated from ORE research results; $C_{w,i}$ the frequency modification can be calculated by frequency weighting curve.

*Note*: GB/T 17247.1-1998 is equivalent to ISO9613-2:1996 "Acoustics-Attenuation of sound during propagation outdoors-Part 2: General method of calculation".

## 4. Prospect for railway environment noise research in China

### 4.1. Amending and drafting of relevant criteria

The existing railway boundary noise standard "Emission standards and measurement methods of railway noise on the boundary alongside railway line" GB12525-90 stipulates that the $A$-weighted equivalent sound level at a distance of 30 m from the centreline of the outer track should not exceed 70 dB. It does not lay down clear requirements for places influenced by railway noise that are further away than 30 m, while GB3096-93 "Urban Area Environment Noise Standard", contains no stipulation with regard to railway noise. So, from the start there has been a linkage problem between GB12525-90 and GB3096-93. Furthermore, because of the economical, technological and ecological differences between countries, there is no unique international standard on railway environmental noise limits. However, in many countries, the limit on railway noise at 30 m away from the centreline of the outer track is no more than 60–65 dB in day time and 55–60 dB at night and obviously lower than that of 70 dB by day/night in China. In order to coordinate with the standards in the rest of the world, the limits in the standard GB12525-90 should be lowered, which would lead to greater protection of the sound environment along railway lines.

### 4.2. *Drafting railway environmental noise control programme*

In China there are 70,000 km of railway lines, controlled by 14 different Railway Bureaus and 35 Railway Sub-bureaus or Railway Companies. It covers a large territory and has great influence. Because of the high speeds and increasing trends towards heavy loading in Chinese railway development, the impact of environmental noise is becoming an acute problem. In order to effectively control it, the Railway Ministry of China is going to set about drafting "Railway Environment Noise Control Program" for environment-friendly metropolitan cities, which will tackle railway noise problem step by step.

### 4.3. *Locomotive whistle noise control*

Locomotive whistles are presently the most important noise source in China. The railway authority has already adopted restrictive measures to reduce the use of whistles in Beijing, Shanghai and Guangzhou, which has had distinct effects on the reduction of noise. But some practical problems still exist, such as security, lack of the funds to build necessary installations, the coordination of local government and residents, etc., and these remain to be solved. Furthermore, under policy guidance, it is necessary to promote the use of whistles which are of low noise and strongly directional to meet the Chinese characteristic situation.

### 4.4. *Research into the characteristics of the noise vibration source of high-speed heavy-load trains and its control*

In China there is a developing trend toward higher speed and heavier load trains and research into noise and vibration source characteristics has not yet touched on these developments. It is expected in the future to import advanced noise source identification equipment and techniques and to be able to use these to study this issue. Again, research into reduction in the noise of Chinese made locomotives is an urgent task.

### 4.5. *The reasonable coordination of railway programming and city construction programming*

Chinese railway construction development is closely linked with city construction. In many cases, the development of cities relies upon the development of the railway. This coincident relationship leads to cities divided by the railway and railway-surrounded cities. So the environmental protection work needs doing in advance, along with the first stage of railway programming and design. While the programming of the railway construction is in progress, the environmental assessment work should begin to evaluate the plan and layout of the railway lines, stations, workshops, depots and terminals. Thus the railway construction can not only meet the needs of transportation but the demands of the environment as well.

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